NATURAL HISTORY,

GENERAL AND PARTICULAR,

BY THE

COUNT DE BUFFON.

VOL. II.

THEORY OF THE EARTH.

GENERAL AND PARTICULAR,

BY THE

COUNT DE BUFFON,

ILLUSTRATED WITH ABOVE SIX HUNDRED COPPER PLATES.

THE

HISTORY OF MAN AND QUADRUPEDS

TRANSLATED, WITH NOTES AND OBSERVATIONS,

BY WILLIAM SMELLIE,

MEMBER OF THE ANTIQUARIAN AND ROYAL SOCIETIES OF EDINBURGH.

A NEW EDITION,

CAREFULLY CORRECTED AND CONSIDERABLY ENLARGED, BY MANY ADDITIONAL ARTICLES, NOTES, AND PLATES,

AND

SOME ACCOUNT OF THE LIFE OF M. DE BUFFON.

BY WILLIAM WOOD, F.L.S.

IN TWENTY VOLUMES.

VOL. II.

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ERRATA.

Page 492, *for* " pl. 3, fig. 1." *read* pl. 9, fig. 1.
538, 539, *for* " pl. 12," *read* pl. 14.
565, line 14, *for* " which" *read* what.

DIRECTIONS TO THE BINDER.

PROOFS

OF THE

THEORY OF THE EARTH

ARTICLE XVI

Of Volcanos and Earthquakes.

THE bowels of those burning mountains called volcanos contain sulphur, bitumen, and other inflammable materials, the effects of which are more violent than those of thunder or of gunpowder; and they have, in all ages, astonished mankind, and desolated the earth. A volcano is an immense cannon, with an aperture often more than half a league in circumference. From this vast mouth are projected torrents of smoke and of flames, rivers of bitumen, of sulphur, and of melted metals, clouds of ashes and stones; and sometimes it ejects, to the distance of several leagues, rocks so enormous, that they could not be moved by any combination of human force. The conflagration is so dreadful, and the quantities of burning, calcined, melted, and vitrified

substances thrown out by the mountain, are so great, that they bury whole towns and forests, cover the plains to the thickness of a hundred or two hundred feet, and sometimes form hills and mountains, which are only portions of these matters heaped up and compacted into one mass. The action of the fire and the force of the explosions are so violent, that they produce, by reaction, succussions, which shake the earth, agitate the sea, overturn mountains, and destroy towns and buildings of the most solid materials.

These effects, though natural, have been regarded as prodigies; and, though we often behold in miniature effects similar to those of volcanos; yet grandeur, from whatever source it proceeds, has such an astonishing influence upon the imagination, that it is not surprising they should have been considered by some authors as vents to a central fire, and, by the vulgar, as mouths of hell. Astonishment produces fear, and fear is the source of superstition. The inhabitants of Iceland believe that the groanings of their volcano are the cries of the damned, and that its eruptions are occasioned by the desperation and ungovernable fury of devils and tormented spirits.

All these phænomena, however, are only the effects of fire and of smoke. In the bowels of mountains, there are veins of sulphur, bitumen, and other inflammable substances, together with vast quantities of pyrites, which ferment when exposed to the air or moisture, and produce explosions proportioned to the quantity of in-

flammable matter. This is the true idea of a volcano; and it is easy for the naturalist to imitate the operation of these subterraneous fires. A mixture of sulphur, of filings of iron, and of water, buried at a certain depth below the ground, will exhibit, in miniature, all the appearances of a volcano: this mixture soon ferments to a degree of inflammation, throws off the earth and stones which cover it, and produces explosions every way similar to those of burning mountains.

The most famous volcanos in Europe are those of Mount Ætna in Sicily, of Mount Hecla in Iceland, and of Mount Vesuvius near Naples in Italy. The burning of Mount Ætna is more ancient than the records of history. Its eruptions are extremely violent; and the quantity of matter it throws out is so enormous, that, after digging sixty-eight feet deep, marble pavements, and other vestiges of an ancient city, have been found covered with this amazing load of ejected matter, in the same manner as the town of Herculaneum has been buried with the matter thrown out from Mount Vesuvius. New mouths, or craters, were opened in Ætna in the years 1650, 1669, and at other times. The smoke and flames of this volcano are seen as far as Malta, a distance of sixty leagues: it sends forth a perpetual smoke, and, at particular times, it throws out, with astonishing violence, flames, lava, huge stones, and matter of every kind. An eruption of this volcano, in the year 1537, produced an earthquake over the whole island of Sicily, which

lasted twelve days, and overthrew an immense number of houses and public buildings. It terminated by the bursting of a new mouth, the lava of which burnt up every thing within five leagues of the mountain. It discharged ashes so abundantly, and with such force, that they reached the coast of Italy, and incommoded vessels at great distances from the island. This volcano has, at present, two principal craters, one of which is narrower than the other. They both smoke perpetually; but flames only appear during the time of eruptions *. Large stones, it is said, have been projected from them to the distance of 60,000 paces.

A violent eruption, in 1683, produced a dreadful earthquake in Sicily. It laid the whole city of Catanea in ruins, and destroyed more than 60,000 of its inhabitants, beside those who perished in the neighbouring towns and villages.

Hecla darts its fires through the snows and ice of a frozen climate. Its eruptions, however, are equally violent with those of Ætna, and other volcanos in the more southern regions. It throws out ashes, lava, pumice stones, and sometimes boiling water. The whole island of Iceland abounds in sulphur; but it is not habitable within less than six leagues of the volcano. The history of its most violent eruptions is recorded in a book written by Dithmar Bleffken.

According to historians, the burning of Mount

* Farelli has given a long description of the eruptions of this mountain.

Vesuvius began not before the seventh consulate of Titus Vespasian and Flavius Domitian. The top of the mountain then opened, and at first threw out stones and rocks. These were succeeded by flames and lava which burnt up two neighbouring cities, and volumes of smoke so thick as to darken the light of the sun. The elder Pliny, stimulated by curiosity, approached too near the mountain, and was suffocated by its sulphureous steams *. Dion Cassius relates, that this eruption was so violent, that ashes and sulphureous steams were transported as far as Rome, and across the Mediterranean into Africa and Egypt. Herculaneum was one of the cities that were overwhelmed by the matter ejected from the mountain: it has lately been discovered sixty feet under the surface of the ground, which, in the course of time, had become arable, and fit for every kind of culture. The history of the discovery of Herculaneum is in the hands of the public. We have only to wish, that some person skilled in the knowledge of nature, would examine with attention the different materials which compose these sixty feet of earth, and remark their situation, the alterations they have undergone, the direction they have followed, the hardness they have acquired, &c.

Naples appears to be situated upon a vault, filled with burning minerals; for Vesuvius and Solfatara seem to have subterraneous communications. When Vesuvius throws out lava, Sol-

* See Pliny the Younger's Letter to Tacitus.

fatara emits flames; and, when the eruptions of the former cease, the burning of the latter is likewise extinguished. The city of Naples is nearly in the centre between them.

One of the last and most dreadful eruptions of Vesuvius happened in the year 1737 *. The mountain discharged from several mouths, immense torrents of melted matter, which spread over the fields, and terminated in the sea. M. de Montealegre, who communicated this account of it to the Academy of Sciences, observed, with horror, one of those rivers of fire, which, from its source to the sea, was about seven miles in length, fifty or sixty paces broad, from twenty-five to thirty palms deep, and in the valleys 120 palms. The running matter resembled foam, or the dross which issues from a furnace †, &c.

The ancients have left us some notices concerning the volcanos which were known to them, and particularly those of Ætna and Vesuvius. Several learned and curious observers have in our days examined more minutely the form and effects of these volcanos. On comparing their descriptions, the first observation that presents itself is, the folly of transmitting to posterity the exact topography of these burning mountains. Their form may be said to change daily; their surface rises or sinks in

* This volume was published in the year 1749. Several eruptions have happened since that time. See Hamilton's History of Vesuvius.

† See l'Hist. de l'Acad. ann. 1737, p. 7.

various places; every eruption produces new gulfs or new eminences: to attempt to describe all these changes, is to follow and paint the successive ruins of a burning edifice. The Vesuvius of Pliny, and the Ætna of Empedocles, present very different aspects from those which have been so ably delineated by Sir William Hamilton and Mr. Brydone; and, in a few ages, these recent descriptions will no longer resemble their objects. Next to the surface of the ocean, nothing on this globe is so fluctuating and inconstant as the surface of volcanic mountains: but even from this inconstancy, and from the variation of form and movements, some general conclusions may be drawn, by bringing particular observations under one point of view.

Of the Changes which have happened in Volcanos.

The base of Ætna is about sixty leagues in circumference, and its perpendicular height about two thousand fathoms above the level of the Mediterranean Sea. We may, therefore, regard this enormous mountain as an obtuse cone, the superficies of which are not less than three hundred square leagues. This conical surface is divided into four zones, situated concentrically above each other. The first is the largest, and, by a gradual ascent, extends above six leagues from the most distant point at the

foot of the mountain. This zone of six leagues broad is almost totally peopled and cultivated. The city of Catania and several villages are situated in this first zone, the surface of which exceeds two hundred and twenty square leagues. The basis of this vast territory consists of various strata of ancient and modern lavas, that have run from different parts of the mountain, from which explosions of subterraneous fires have issued. The surface of this lava, mixed with ashes thrown out from different craters, is converted into a fine soil, which is now sown with grain and planted with vines, except in a few places where the lava is too recent, and still remains uncovered with earth. About the top of the zone, we still see several craters, more or less large and deep, from which the materials issued that have formed the upper stratum or soil.

The second zone commences at the termination of these six leagues. This second zone is an ascent of about two leagues broad. Its declivity is every where more rapid than that of the first zone; and this rapidity augments in proportion as you approach toward the summit. The surface of this second zone is about forty or forty-five square leagues: its whole extent is covered with magnificent forests, and forms a fine belt of verdure to the white and hoary head of this venerable mountain. The soil of these fine forests is nothing but lava and ashes converted by the operation of time into excellent earth. What is still more remarkable, the surface of this zone is so unequal, that it

every where presents hills, or rather mountains, all of which have been produced by different eruptions from the summit of Ætna, and other craters below the summit, several of which have formerly acted in this very zone, now converted into forests.

Before arriving at the summit, and after having passed these fine forests, we traverse a third zone, which gives birth to small vegetables only. In winter, this region is covered with snow, which melts in summer. We afterwards meet with a line of permanent snow, which marks the commencement of the fourth zone, and extends to the top of the mountain. These snows and ice occupy about two leagues from the region of small vegetables to the summit, which is likewise covered with snow and ice. Its figure is an exact cone; and it contains the great crater of the volcano, from which are continually discharged immense volumes of smoke. The internal figure of the crater is that of an inverted cone. It is composed of nothing but ashes and other burnt matters thrown out by the mouth of the crater, which is in the centre of the volcano. The external surface of the summit is very rough. The snow is covered with ashes, and the cold is very piercing. On the north side of this region of snow, there are several small lakes, which never freeze. In general, the surface of this last zone is pretty equal, and observes the same declivity, except in a few places; and it is below this region only where we meet with a great number of inequalities, eminences, and

hollows, produced by eruptions, and where we see hills and mountains more or less recently formed, and composed of burnt matters rejected by these different mouths or craters.

In 1770, according to Mr. Brydone, the crater on the top of Ætna was more than a league in circumference; and very different dimensions have been ascribed to it both by ancient and modern authors. All these authors, however, were right; for the dimensions of this mouth of fire have undergone many alterations. All we can infer from the various descriptions that have been given of it, is, that the crater, with its margins, has been four times overturned within these six or seven hundred years. The materials of which it is composed fall back into the bowels of the mountain, are again rejected by fresh eruptions, and form a new crater, which augments and rises by degrees, till it again falls back into the great gulf of the volcano.

The top of the mountain is not the only place from which the subterraneous fire has been discharged. Through the whole territory which forms the sides and ridge of Ætna, and at great distances from the summit, there are many craters, which give passage to the fire, and which are surrounded with broken rocks, that had been discharged by different eruptions. We may even reckon several hills, formed by the eruptions of these small volcanos, which surround the great one. Each of these hills has a crater at its top, in the centre of which is a deep mouth or gulf. Every eruption of Ætna has produced a new

mountain; and, perhaps, Mr. Brydone remarks. their number would determine, better than any other method, that of the eruptions of this famous volcano.

The city of Catania, which is situated at the foot of Mount Ætna, has often been laid in ruins by the lavas which issued from these new mountains during the time of their formation. In ascending from Catania to Nicolosi, we traverse twelve miles through a country formed by ancient lavas, where we see the mouths of extinguished volcanos, which at present are fertile lands, covered with grass, corn, and vineyards. The lavas which form this region proceeded from the eruptions of the small mountains, which are every where dispersed over the sides of Ætna: they are all, without exception, either regular hemispheres or cones. In general, every eruption raised one of these mountains. Hence the action of the subterraneous fires does not always reach the summit of Ætna. They often issue from the sides, and even from the foot of this burning mountain. Each eruption from the sides of Ætna commonly produces a new mountain, composed of rocks, stones, and ashes, projected to a great distance by the force of the fire; and the magnitude of these new mountains is proportioned to the duration of the eruption. If it continues but a few days, it produces only a little hill, about a league in circumference at the base, and three or four hundred feet in perpendicular height. But, if the eruption continues some months, like that of 1669, it then gives rise to a

considerable mountain of two or three leagues in circumference, and 900 or 1,000 feet high; and all these hills, produced by Ætna, some of which are 1,200 feet high, appear only as small elevations intended to accompany the majesty of the parent mountain.

In Vesuvius, which is a very small volcano when compared with Ætna, eruptions from the sides of the mountain are rare, and the lava generally issues from the crater at the summit. But, in Ætna, eruptions more frequently proceed from the sides than the top, and lava issues abundantly from every new mountain formed by these eruptions. Mr. Brydone, according to the information he received from M. Recupero, says, that the masses of stones, projected from Ætna, rise to such a height, that they take twenty-one seconds of time in descending to the earth; while those of Vesuvius fall in nine seconds: hence the stones projected by Vesuvius rise to the height of 1,215 feet, and those projected by Ætna rise 6,615 feet; from which we may conclude, if the observations be accurate, that the force of Ætna is to that of Vesuvius as 441 to 81, *i. e.* five or six times greater. That Vesuvius is a very feeble volcano, when compared to Ætna, is proved in a more forcible manner by this circumstance, that Ætna has actually produced other volcanos, which are larger than that of Vesuvius.

"Not a great way from this cavern," says Brydone, "are two of the most beautiful mountains of all that number that spring from Ætna. I mounted

one of our best mules, and, with a good deal of difficulty, arrived at the summit of the highest of them just a little before sun-set. The prospect of Sicily, with the surrounding sea and all its islands, was wonderfully noble. The whole course of the river Semetus, the ruins of Hybla, and several other ancient towns; the rich corn-fields and vineyards on the lower region of the mountain, and the amazing number of beautiful mountains below, made a delightful scene. The hollow craters of these two mountains are each of them considerably larger than that of Vesuvius. They are now filled with stately oaks, and covered to a great depth with the richest soil. I observed that this region of Ætna, like the former, is composed of lava; but this is now covered so deep with earth, that it is no where to be seen, but in the beds of the torrents. In many of these it is worn down by the water to the depth of fifty or sixty feet, and in one of them still considerably more. . . . This conical mountain is of a very great size; its circumference cannot be less than ten miles. Here we took a second rest, as the greatest part of our fatigue still remained The mercury had fallen to 20: 4½.— We found this mountain excessively steep; and although it had appeared black, yet it was likewise covered with snow. . . . . The present crater of this immense volcano is a circle of about three miles and a half in circumference. It goes shelving down on each side, and forms a regular hollow, like a vast amphitheatre. From many places of this space, issue volumes of sulphureous smoke,

which, being much heavier than the circumambient air, instead of rising in it, as smoke generally does, immediately on its getting out of the crater, rolls down the side of the mountain like a torrent, till, coming to that part of the atmosphere of the same specific gravity with itself, it shoots off horizontally, and forms a large track in the air, according to the direction of the wind; which, happily for us, carried it exactly to the side opposite to that where we were placed. The crater is so hot, that it is very dangerous, if not impossible to go down into it; besides, the smoke is very incommodious, and, in many places, the surface is so soft, there have been instances of people sinking down in it, and paying for their temerity with their lives. Near the centre of the crater is the great mouth of the volcano . . . . When we arrived at the foot of the cone, we observed some rocks of an incredible size, that have been discharged from the crater. The largest that has been observed from Vesuvius, is a round one of about twelve feet in diameter. These are much greater; indeed almost in proportion of the mountains to each other."

As all that region from the top of Ætna, to the distance of two leagues below, presents an equal surface, without hills or valleys, and as the ruins of Empedocles, the philosopher's tower, who lived 400 years before the Christian æra, are still to be seen, it is probable, that, during all this period, the great crater has made few or no eruptions. Hence the force of the fire

has diminished, as it no longer acts with violence at the summit, and as all the modern eruptions have happened in the lower regions of the mountain. However, within these few centuries, the dimensions of the great crater have been often changed, as appears from the measurements of Sicilian authors at different periods. Sometimes it falls down, and is again gradually elevated till it falls afresh. The first of these fallings, which are well attested, happened in the year 1157, a second in 1329, a third in 1444, and the last in 1669. But, from these facts, we should not conclude, as Mr. Brydone has done, that the crater will soon suffer another overthrow. The notion, that this effect should be produced every hundred years, seems to have no foundation. I should rather imagine, that, as the fire no longer acts with violence at the summit, its force has diminished, and will continue to diminish, in proportion as the sea retires: it has already retired several miles by the action of the volcano, which has formed large banks and bulwarks by vast torrents of lava. Besides, we know, from the diminished rapidity of Scylla and Charybdis, and several other indications, that the Sicilian Sea has sunk considerably within these 2,500 years. We may, therefore, conclude, that this sea will continue to sink, and, of course, that the action of the neighbouring volcanos will not relax; so that the crater of Ætna may remain during a long time in its present state; and, if ever it falls back into the gulf, it will probably be for the last time. I farther

presume, that Ætna ought to be regarded as one of the primitive mountains, on account of its height and the immensity of its size, and that it began to act at the remote period when the waters first retreated. Its action, however, ceased after this retreat, and was not renewed till that modern period when the Mediterranean Sea, being elevated by the rupture of the Bosphorus and the straits of Gibraltar, deluged the land between Sicily and Italy, and approached to the basis of Ætna. Perhaps the first of these eruptions is still posterior to this epoch of Nature. "It is evident," Mr. Brydone remarks, "that Ætna did not burn in the days of Homer, nor for a long time before, otherwise it would have been impossible that this poet should have talked so much of Sicily, without mentioning an object so astonishing." This remark of Mr. Brydone is extremely just; and, *of course, the first known eruptions of Ætna should be dated after the age of Homer.* But we perceive, from the poetical allusion of Pindar and Virgil, and from the descriptions of ancient and modern authors, that, in the space of eighteen or nineteen centuries, the whole face of this mountain and of the adjacent country has been changed by earthquakes, eruptions, torrents of lava, and the formation of hills and gulfs by these commotions. For the facts above related I am indebted to Mr. Brydone's excellent performance; and I have too high an esteem for Mr. Brydone to believe that he can be offended, because I do not agree with him as to the force of volcanos, and some other

conclusions he has drawn from these facts. No preceding author has observed with equal acuteness, or presented such lively pictures of the objects he surveyed; the whole republic of letters, therefore, ought to unite in celebrating a work so deserving of praise.

Torrents of glass in fusion, which have received the denomination of lavas, are not the first effects of eruptions. These eruptions are commonly announced by an earthquake more or less violent, which is the first effort of the subterraneous fire to escape from the bowels of the earth: it soon, however, opens a passage, which it enlarges by projecting rocks and every other obstruction to its motion. These materials, which are exploded to a great height, fall back upon each other, and form an eminence more or less considerable in proportion to the duration and violence of the eruption. As all the ejected matters are penetrated by fire, and most of them converted into burning ashes, the eminence to which they give rise is a mountain of solid fire, in which a great part of the matter is melted by the fervency of the heat. This melted matter soon begins to run, and generally flows to the foot of the new mountain by which it was produced. But, in small volcanos, which have not force sufficient to throw the ejected matters to a great distance, the lava issues from the top of the mountain. This effect is conspicuous in the eruptions of Vesuvius. The lava rises in the centre of the crater. The volcano first throws out stones and ashes, which fall perpendicularly

back into the old crater and augment its size. It is through this additional matter, which has fallen back, that the lava opens a passage. These *two effects, though different in appearance, are* nevertheless the same; for in a small volcano, which, like Vesuvius, has not force enough to give birth to new mountains *by projecting* its materials to a distance, the whole *fall back upon* the summit, and increase its height; and it is at the foot of this new *crown of matter that the lava forces its way and flows down the mountain.* This last effort is generally succeeded by a repose of the volcano. The succussions of the earth within, and the projections without, cease as soon as the lava flows. But the torrents of this glass in fusion produce effects still more extensive and disastrous than the convulsions of the mountain during an eruption. These rivers of fire ravage, destroy, and disfigure the surface of the earth. Nothing can oppose their dreadful progress. Of this the unfortunate inhabitants of Catania have had fatal experience. As their city had often been destroyed, either wholly or in part, by these torrents of lava, they built very strong walls of fifty-five feet in height. Surrounded by these ramparts, they believed themselves to be safe. The walls, it is true, resisted the heat and the weight of the torrent. But this resistance served only to dam up the lava, which rose above the ramparts, fell back upon the city, and ravaged every thing in its progress.

These torrents of lava are often half a league, and sometimes even two leagues broad.

"The last lava we crossed before our arrival at Catania, is of a vast extent. I thought we never should have done with it; it certainly is not less than six or seven miles broad, and appears in many places to be of an enormous depth.

"When we came near the sea, I was desirous to see what form it had assumed in meeting with the water. I went to examine it, and found it had driven back the waves for upwards of a mile, and had formed a large black high promontory, where before it was deep water. This lava, I imagined, from its barrenness, for it is as yet covered with a very scanty soil, had run from the mountain only a few ages ago; but was surprised to be informed, by Signior Recupero, the historiographer of Ætna, that this very lava is mentioned by Diodorus Siculus to have burst from Ætna in the time of the second Punic war, when Syracuse was besieged by the Romans. A detachment was sent from Taurominum to the relief of the besieged. They were stopped on their march by this stream of lava, which, having reached the sea before their arrival at the foot of the mountain, had cut off their passage; and obliged them to return by the back of Ætna, upwards of 100 miles about. His authority for this, he tells me, was taken from inscriptions on Roman monuments found on this lava, and that it was likewise well ascertained by many of the old Sicilian authors. Now, as this is about 2,000 years ago, one would have imagined, if lavas have a regular progress in becoming fertile

fields, that this must long ago have become at least arable; this, however, is not the case, and it is as yet only covered with a very scanty vegetation, and incapable of producing either corn or vines. There are indeed pretty large trees growing in the crevices, which are full of a rich earth; but in all probability it will be some hundred years yet, before there is enough of it to render this land of any use to the proprietors.

"We passed the river Alcantara on our way to Piedmonte, over a large bridge built entirely of lava; and near to this the bed of the river is continued for a great way, through one of the most remarkable, and probably one of the most ancient lavas that ever run from Ætna. In many places the current of the river, which is extremely rapid, has worn down the solid lava to the depth of fifty or sixty feet. Recupero, the gentleman I have mentioned, who is engaged in *writing the Natural History of Ætna, tells me, he had* examined this lava with great attention, and he thinks that its course, including all its windings, is not less than forty miles. It issued from a mountain on the north side of Ætna, and, finding some valleys that lay to the east, it took its course that way, interrupting the Alcantara in many places, and at last arrived at the sea, not far from the mouth of that river.

"The city of Jaci or Aci, and indeed all the towns on this coast, are founded on immense rocks of lava, heaped one above another, in some places to an amazing height; for it appears that

these flaming torrents, as soon as they arrived at the sea, were hardened into rock, which not yielding any longer to the pressure of the liquid fire behind, the melted matter continuing to accumulate, formed a dam of fire, which, in a short time, run over the solid front, pouring a second torrent into the ocean: this was immediately consolidated, and succeeded by a third, and so on . . . . The road from Jaci to this city is entirely over lava, and consequently very fatiguing and troublesome. Within a few miles of that place, we counted eight mountains formed by eruptions, with every one its crater, from whence the burnt matter was discharged. Some of these are very high, and of a great compass. It appears evidently, that the eruptions of Mount Ætna have formed the whole of this coast, and in many places have driven back the sea for several miles from its ancient boundary. . . . . . At Catania, near to a vault which is now thirty feet below ground, and has probably been a burial place, there is a draw-well, where there are several strata of lavas, with earth to a considerable thickness over the surface of each stratum. Recupero has made use of this as an argument to prove the great antiquity of the eruptions of this mountain. For if it requires two thousand years or upwards to form but a scanty soil on the surface of a lava, there must have been more than that space of time betwixt each of the eruptions which have formed these strata. But what shall we say of a pit they sunk near to Jaci,

of a great depth? They pierced through seven distinct lavas, one under the other, the surfaces of which were parallel, and most of them covered with a thick bed of rich earth. 'Now,' says he, 'the eruption which formed the lowest of these lavas, if we may be allowed to reason from analogy, must have flowed from the mountain at least 14,000 years ago.' . . .

"The great eruption of 1669, after shaking the whole country around for four months, and forming a very large mountain of stones and ashes, burst out about a mile above Monpelieri, and, descending like a torrent, bore directly *against the middle of that mountain*, and (they pretend) perforated it from side to side: this, however, I doubt, as it must have broken the regular form of the mountain, which is *not the case. But certain it is, that it pierced it to a great depth.* The lava then divided into *two branches; and,* surrounding this mountain, joined again on its south side; and, laying waste the whole country betwixt that and Catania, scaled the walls of that city, and poured its flaming torrent into the ocean. In its way, it is said to have destroyed the possessions of near 30,000 people, and reduced them to beggary. It formed several hills where there were formerly valleys, and filled up a large lake, of which there is not now the least vestige to be seen . . . There is no part of the coast from Catania to Syracuse nearer than thirty miles to its summit; and yet there has hardly been any great erupti

lava has not reached the sea, and driven back its waters to a great distance, leaving high rocks and promontories, that for ever set its waves at defiance, and prescribe their utmost limits. What a tremendous scene must the meeting betwixt these adverse elements have formed!

"We may easily conceive the variety of changes this coast has undergone in the space of some thousands of years, as every great eruption must have made a considerable difference.—Virgil is wonderfully minute and exact in his geography of Sicily; and this is the only part of the island that seems to be materially altered since his time. He says there was a very large port at the foot of Ætna, where ships were secure from every wind;

'Portus ab accessu ventorum immotus et ingens;'

of which, at present, there are not the least remains. It is probably the same that was called by the Sicilians the port of Ulysses; which is often mentioned by their writers.—The place of its existence is still shown betwixt three and four miles up the country, amongst the lavas of Ætna. . . . . .

"The circumference of the great base of Ætna, Recupero told me, he had been at a good deal of pains to ascertain; as it had generally been computed only at 100 miles, or little more, although the radii of that circle had ever been esteemed at thirty of those miles; an absurdity in computation that had put him upon making this inquiry. The result was, that, taking the supposed distances of one place

from another all the way round, the sum of the whole amounted to 183 miles: an immense circle surely, and which is still enlarged by every considerable eruption."

Here we have a territory of about 300 superficial leagues, all covered or formed by the projections of volcanos. In this territory, independent of the peak of Ætna, there are many other mountains, all of which are furnished with craters, and exhibit an equal number of particular volcanos. Ætna, therefore, must not be regarded as a single volcano, but as an assemblage of volcanos, the greater part of which are extinguished, or burn with a gentle fire, and a few of them still act with violence. At present, the summit of Ætna throws out nothing but smoke; and there seems to have been no eruption from it for a very long period of time; because it is surrounded, to the distance of two leagues, with an equal surface, and below this high region, covered with snow, we find a large zone of vast forest, the soil of which is a fertile earth of several feet in thickness. This inferior zone is interspersed with inequalities, and presents heights, valleys, hills, and even pretty large mountains. But, as almost the whole of these inequalities are covered with a great thickness of earth, and as a long succession of time was necessary to convert volcanic matters into vegetable soil, we should regard the summit of Ætna, and the other mouths which surround it, to the distance of four or five leagues, as volcanos almost extinct, or, at least, stifled for a number of ages; for all the eruptions, the dates

of which can be ascertained for 2,500 years, have happened in the lower region, *i. e.* five, six, or seven leagues distant from the summit. The volcanos of Sicily seem to have had two different ages: the first very ancient, when the summit of Ætna began to act, and when the universal ocean left this summit dry, and sunk some hundreds of fathoms below: it was at this period that the first eruptions happened, which produced lava at the summit, and gave rise to those hills found below in the region of forests; but afterwards, the waters continuing to sink, they totally abandoned this mountain, as well as all the territories of Sicily and the adjacent continents. After this total retreat of the waters, the Mediterranean was only a lake of a moderate extent, and its waters were very distant from Sicily, and all the countries whose coasts it now washes. During all this time, which lasted several thousand years, Sicily was perfectly tranquil: Ætna, and the other ancient volcanos which surround its summit, had ceased to act; and it was not till after the augmentation of the Mediterranean by the waters of the ocean and of the Black Sea, *i. e.* after the rupture of the straits of Gibraltar and of the Bosphorus, that the waters attacked the bases of the new mountains of Ætna, and produced those modern eruptions, which have happened since the age of Pindar to the present time; for this poet is the first author who has taken notice of eruptions of volcanos in Sicily. Vesuvius was precisely in the same situation: it was long one of the extinguished vol-

canos of Italy, which are very numerous; and their eruptions were not renewed till after the waters of the Mediterranean were increased, and reached the bases of these inflammable mountains. The memory of the first eruptions, and even of all those which preceded the age of Pliny, was entirely obliterated. Neither should this circumstance excite surprise; for ten thousand years have perhaps elapsed since the general retreat of the waters to the augmentation of the Mediterranean, and an equal portion of time from the first eruption of Vesuvius till their removal. All these considerations seem to prove, that subterraneous fires cannot act with violence, unless when they are so near the sea as to receive a shock from a great body of water. This reasoning is confirmed by other phænomena: volcanos sometimes throw out great quantities of water, and likewise torrents of bitumen. P. de la Torré, an able philosopher, relates, "that, on the 10th of March, 1755, an immense torrent of water issued from the foot of the mountain, which deluged the neighbouring country. This torrent brought down such a quantity of sand, that it covered an extensive plain. These waters were very hot. The stones and sand left on the plain differed not from those found in the sea. The torrent of water was immediately followed by another of inflamed matter, which proceeded from the same opening *."

* Hist. du Mont Vesuve, par le P. J. M. de la Torré; Journal Etranger, mois Janvier, 1576, p. 203.

"The same eruption, 1755, was preceded," says M. d'Arthenay, "by an inflammation so great, that it illuminated more than twenty-four miles of country along the coast of Catania. The explosions were soon so frequent, that, on the 3d of March, we perceived a new mountain in the top of the old summit, in the same manner as lately happened to Vesuvius. Lastly, the magistrates of Mascali informed us, that, on the 9th of the same month, the explosions were terrible; that the whole sky was darkened with smoke; that, on the approach of night, it began to rain a deluge of small stones, some of which weighed three ounces, and covered all the adjacent cantons; that this tremendous rain continued an hour and a quarter, and was succeeded by another of black ashes, which lasted the whole night; that next day, about eight o'clock in the morning, the summit of Ætna threw out a river of water, which, for magnitude, might be compared to the Nile; that the most ancient and rugged mountains of lava were in an instant converted by this torrent into a vast plain of sand; that the water, which fortunately ran not above half a quarter of an hour, was very hot; that the stones and sand carried along with it differed not from those of the sea; that, after this inundation, there issued from the same mouth a small rivulet of fire, which flowed during twenty-four hours; that, on the 11th, about a mile below this mouth, a rent happened, through which issued a stream of lava, of about a hundred fathoms broad by

two miles in length, and that it continued its course through the country the same day in which M. d'Arthenay wrote this relation *."

Let us attend to what Mr. Brydone has remarked concerning this eruption: "Part of the fine forests which compose the second region of Ætna was destroyed by a very singular event, not later than the year 1755. During an eruption of the volcano, an immense torrent of boiling water issued, as is imagined, from the great crater of the mountain, and in an instant poured down to its base; overwhelming and ruining every thing it met with in its course. Our conductors showed us the traces of this torrent, which are still very visible; but are now beginning to recover verdure and vegetation, which for some time appeared to have been lost. The track it has left seems to be about a mile and a half broad; and in some places still more.

"The common opinion, I find, is, that this water was raised by the power of suction, through some communication betwixt the volcano and the sea; the absurdity of which is too glaring to need a refutation. The power of suction alone, even supposing a perfect vacuum, could never raise water to more than thirty-three or thirty-four feet, which is equal to the weight of a column of air the whole height of the atmosphere."

I must here observe, that Mr. Brydone seems

* Mem. des Savans Etrangers, imprimés comme suite des Mem. l'Acad. des Sciences, tom. iv. p. 147.

to have deceived himself; for he confounds the force arising from the weight of the atmosphere with the force of suction produced by the action of fire. The force of the air, when a vacuum is made, is indeed limited to thirty-four feet. But the force of suction by fire has no limits: it is always proportioned to the quantity and intensity of the heat by which it is produced, as is evident from the common effects of blast furnaces. Hence the opinion of the *enlightened people of the country*, instead of being absurd, seems to be well founded. It is necessary that the cavities of volcanos should communicate with the sea: without this communication, such immense torrents of water could not be thrown out, nor indeed could any eruption ever happen; for no power, except the shock produced by the mingling of fire and water, could give rise to such violent effects.

The volcano of Pacayita, called the water volcano by the Spaniards, in all its eruptions, throws out torrents of water. The last eruption, in the year 1773, destroyed the city of Guatimala, and the torrents of water and lava descended to the South Sea.

With regard to Vesuvius, it has been remarked, "that a wind, which blows from the sea, penetrates into the mountain. The noise it makes in certain cavities is heard, as if some torrent passed below: this noise ceases whenever the land winds blow, and, at the same time, the exhalations from the mouth of Vesuvius become less considerable. But, when the wind

blows from the sea, this noise, which resembles that of a torrent, recommences, and the exhalations of flame and smoke increase.. The *water of the sea, by thus insinuating itself into the mountain, sometimes in greater, and sometimes in smaller quantities, is the reason why this volcano has often thrown out both ashes and water* *."

The learned M. d'Arthenay; who has compared the modern with the ancient state of Vesuvius, relates, "that, during the interval which preceded the eruption 1631, the funnel or crater of the mountain was covered with trees and verdure; that the small plain which bounds it produced excellent pasture; that, in departing from the superior margin of the crater, we have a mile to descend before we arrive at this plain, in the middle of which was another gulf. We descended this gulf about a mile, by narrow and winding roads of an equal declivity, which led into a vast space surrounded with caverns, from whence there issued *winds so impetuous and so cold, that it was impossible to endure them.*" According to the same observer, the summit of Vesuvius was then five miles in circumference. We should not therefore be surprised, that some philosophers have maintained that what seems now to be two mountains, was formerly one; that the volcano was in the centre, but that the south side, having fallen by the force of some

* Descript. Historique et Philos. de Vesuve, par. Mr. l'Abbé Mecatti; Journal Etranger, mois Oct. 1754.

eruption, produced the valley which separates Vesuvius from Mount Somma *.

M. Steller remarks, "that the volcanos in the north of Asia are almost always isolated; that they have nearly the same surface; and that there are always lakes on the summits, and hot waters at the foot of those mountains whose volcanos are extinct. This," he adds, "is a farther proof of the correspondence established by nature between the sea, mountains, volcanos, and hot waters." We find many springs of hot water in different parts of Kamptschatka †. In the island of Sjanw, forty leagues distant from Ternate, there is a volcano, which often throws out water, ashes ‡, &c. But it is unnecessary to accumulate more facts to prove the communication of volcanos with the sea. The violence of their eruptions would be sufficient to justify the presumption; and the general fact, that all acting volcanos are situated near the sea, completes the demonstration. However, as some philosophers have denied the reality and even the possibility of this communication of volcanos with the sea, I shall mention another fact, related by M. de la Condamine, a man equally enlightened as worthy of credit. "On the 14th of June, 1755," he remarks, "I mounted to the summit of Vesuvius, and even to the brink of the funnel formed

* Observ. sur le Vesuve, par M. d'Arthenay; Journal de Savans Etrangers, tom. iv. p. 147.

† Hist. Gen. des Voyages, tom. xix. p. 238.

‡ Ibid. tom. xvii. p. 54.

round the mouth of the volcano by its last explosion; and I perceived in the gulf, about forty fathoms deep, a great cavity resembling a vault toward the north of the mountain. I threw down large stones into this cavity, and counted twelve *seconds before the noise of their rolling ceased. At the end of their fall* I heard a noise similar to that of a stone falling into a mire; and, when nothing was thrown in, I heard a noise like that of agitated waves *." If the fall of the stones had been perpendicular, and met with no obstacle, twelve seconds would have given a depth of 2,160 feet, and the bottom of the gulf would, on this supposition, be deeper than the level of the sea; for, according to le P. de la Torré, in 1753, this mountain was only 1,677 feet above the surface of the sea, and this elevation has been diminished since that period. Hence we may conclude, that the caverns of this volcano descend below the level of the sea, and, of course, they may have subterraneous communications.

On the 15th of July, 1753, I received, from an eye-witness, and an accurate observer, a distinct detail of the then condition of Vesuvius. I shall subjoin it in the words of the author, because it will tend to fix our ideas concerning what is to be farther apprehended from the effects of this volcano, the force of which seems to be greatly diminished.

"Having arrived at the foot of the mountain,

* Voyage en Italie, par M. de la Condamine; Mem. de l'Acad. des Sciences, ann. 1757, p. 371.

which is about two leagues distant from Naples; we mounted during an hour and a half upon asses, and an equal portion of time was employed in completing the journey on foot. This is the steepest and most fatiguing part of the way. We held by the belts of two men who went before, and we climbed among ashes and stones formerly exploded.

"In our ascent, we saw the lavas of different eruptions. The most ancient, whose age is uncertain, but tradition assigns it 200 years, is of an iron-gray colour, and has all the appearance of a stone: it is used for paving the streets of Naples, and in other works of masonry. We found others, which were said to be sixty, forty, and twenty years old. The last was thrown out in the year 1752 . . . . These different lavas, except the most ancient, when viewed at a distance, have the appearance of a blackish brown rugged earth, more or less recently laboured. When viewed nearer, it is a matter perfectly similar to the refuse of iron foundries. It is more or less composed of earth and ferruginous matter, and approaches more or less to the nature of stone.

"When arrived at the top, which, before the eruption, was solid, we find the first basin, whose circumference is said to be two Italian miles, and its depth appears to be about forty feet. It is surrounded with a crust of earth, which gradually thickens toward the base, and its upper margin is two feet broad. The bottom of this basin is covered with a greenish yellow sulphureous matter,

which is hard and warm, but does not burn; and *smoke issues through different fissures.*

" *In the centre of this basin we see a second, which is about half the circumference and half the depth of the former.* Its bottom is covered with a blackish brown matter, similar to the freshest lavas we find on the road.

" *In the second basin, there is a small mount* which is hollow internally, open at the top, and likewise open from the top to the base toward that side of the mountain where we ascended. This lateral opening is about twenty feet broad at the top, and four feet at the base. The height of this small mount is about forty feet; the diameter of the base is about as much, and that of the opening at the top about twenty feet.

" This base rises about twenty feet above the second basin, and forms a third basin, which is filled with a liquid and burning matter, and has a perfect resemblance to the melted metal in an iron furnace. This matter perpetually boils with great violence. Its movements have the appearance of a lake moderately agitated, and the noise it produces is similar to that of waves.

" Every minute, quantities of this matter are projected into the air, like water thrown up by many jets-d'eaux. These projections produce the appearance of burning sheafs of wheat, which rise to the height of thirty or forty feet, and fall back in various curves, partly into their own basin, and partly the second, which is

covered with a black matter. It is the reflected light of these burning jets which is seen from Naples during the night. The noise they make in their elevation and fall seems to be composed of that of fire-works, and the noise produced by the waves of the sea, when violently dashed against a rock.

" The boilings and jets produce a perpetual evacuation of this matter. Through the aperture of four feet, at the base of the small mount, a burning rivulet, of the same dimensions with the aperture, continually flows, and descends in an inclined canal, and with a mean movement, into the second basin, where, after dividing into several rills, it stops and is extinguished.

" This burning rivulet consists of fresh lava, which runs only eight days. But, if it continues to augment, it will in time produce a new overflowing into the plain, similar to that which happened two years ago. The whole is accompanied with a thick smoke, which has not the odour of sulphur, but precisely that which proceeds from a furnace where tiles are roasted.

" We may, without danger, go round the margin of the crater; because the little hollow mount, from which the burning projections are made, is sufficiently distant to prevent all apprehensions. We may also, without danger, descend into the first basin; we may even go upon the margin of the second, if the reverberation of the burning matter does not prevent us

"This was the real state of Vesuvius on the 15th of July, 1753. *But it perpetually changes* its form and aspect. It now throws out no stones, and we perceive no flame*."

These observations seem to prove, that the seat of the burning in this volcano, and perhaps in all others, is at no great depth in the bowels of the mountain, and that it is not necessary to suppose their fires on a level with, or lower than the sea, and to make their explosions from thence during the time of eruptions. It is sufficient that there are caverns and perpendicular fissures below, or rather at the side of the fire, which serve as ventilators to the furnace of the volcano.

M. de la Condamine, who has had more opportunities than any other philosopher, of examining a number of volcanos in the Cordeliers, has likewise explored that of Vesuvius, and all the adjacent territories.

"In the month of June, 1755," he remarks, "the summit of Vesuvius formed an open funnel in a mass of ashes, calcarious stones, and sulphur, which burned at different distances, and tinged the surface with its colour. The fire streamed through different crevices, in which the heat was so great, that, in a short time, it inflamed a stick thrust some feet down these fissures.

"For several years past, the eruptions of this

* Note sent to M. de Buffon from Naples, in September, 1753.

volcano have been frequent; and, every time flames and liquid matter were thrown out, the mountain underwent considerable changes both in its height and external figure. . . . . In a small plain on the side of the mountain, composed of ashes and stones projected from the volcano, there is a breast of steep semicircular rocks, of 200 feet high, which bound this plain on the north. We perceived, near the crevices recently opened in the flanks of the mountain, the places through which the torrents of lava, with which the whole of this valley is filled, had issued during the last eruption.

"This spectacle presents the appearance of metallic waves cooled and congealed. We may form an imperfect idea of it by imagining a sea of thick and tenacious matter, the waves of which had begun to calm. This sea has its islands; they are detached masses, like hollow spongy rocks, whimsically interspersed with vaults and grottos, under which the burning liquid had made a kind of reservoirs, resembling furnaces. From these grottos, with their vaults and pillars, hang numbers of scoriæ, in the form of irregular grapes, of all shades and colours. . . . . . .

"All the mountains and coasts in the environs of Naples, are nothing but masses of burnt matter thrown out by volcanos which now no longer exist, and whose eruptions, which have been anterior to all history, probably formed the ports of Naples and Puzzoli. The same

matters are conspicuous on the whole road from Naples to Rome, and even at the port of Rome itself.

" The whole interior part of Mount Frascati, *the chain of hills which extends from this place to Grotta-ferrata, Castlegandolfo, and as far as* Lake Albano, a great part of Mounts Tivoli, Caprarola, Viterbe, &c., are composed of calcined stones, of pure ashes, of scoriæ, of matter similar to the dross of iron and burnt earth, and *of real lava; lastly, the whole matters resemble* those of which the soil of Portici is composed, and which have issued from the sides of Vesuvius in so many different forms. . . . . . . Hence we must necessarily conclude, that all this part of Italy has been overturned by volcanos. . . . .

" Lake Albano, whose margins are interspersed with calcined matters, is nothing but the mouth of an ancient volcano. . . . . The chain of Italian volcanos extends as far as Sicily, and still exhibits a number of fires under different forms; in Tuscany, we have the exhalations of Firenzuola, and the warm waters of Pisa; in the Ecclesiastic State, those of Viterbe, of Norcia, of Nocera, &c.; in the kingdom of Naples, those of Ischia, Solfatara, and Vesuvius; in Sicily and the islands adjacent to Ætna, the volcanos of Lipari, Stromboli, &c. The other volcanos of this chain have been extinct from time immemorial, and have left such relics, as, though they do not always strike us at first sight, fail

not to be recognisable on an attentive examination*."

"It is very probable," says M. l'Abbé Mecati, "that, in past ages, the kingdom of Naples, besides Vesuvius, was infested with several other volcanos."

"Mount Vesuvius," le P. de la Torré remarks, "seems to be a portion detached from that chain of mountains which, under the name of Appennines, divides all Italy through its whole length. . . . . . This volcano is composed of three different mountains: one of them Vesuvius, properly so called; the other two are Mounts Somma and Otajano. The two last are situated toward the west, and form a kind of semicircle round Vesuvius, with which they have a common base.

"This mountain was formerly surrounded with fertile fields, and itself covered with trees and verdure, except the summit, which was flat and sterile, and where several open caverns were to be seen. The top was surrounded with rocks, which rendered it of difficult access. These rocks were so high, that they concealed the valley between Vesuvius and Mounts Somma and Otajano. The summit of Vesuvius, which has since sunk considerably, being then much more remarkable, it is not surprising that the ancients believed it had only one top. . . . .

"The breadth of the valley is 2,220 Paris feet, and its length nearly the same. . . . . .

* Voyage en Italie, par M. de la Condamine: Acad. des Sciences, ann. 1757, p. 371–379.

It invests one half of Vesuvius, and, like all the sides of the mountain, it is covered with burnt sand and small pumice stones. The rocks on Mounts Somma and Otajano exhibit a few herbs, *and the surface of these mountains is covered with trees and verdure.* These rocks, at first sight, have the appearance of burnt stones; but, on a closer examination, they are, like the rocks of other mountains, composed of strata of natural stones, of a chesnut-coloured earth, of chalk, and of white stones, which have not the smallest appearance of having been liquified by fire. . . .

" Round Vesuvius we see openings which have been made at different times, and through which lavas had issued. These torrents of burning matter, which sometimes come from the sides, and sometimes from the top of the mountain, descend into the plains, and sometimes run as far as the sea, and harden like a stone when the matter cools. . . . .

" On the summit of Vesuvius there is only a small margin of four or five palms wide, which describes a circumference of 5,624 Paris feet. Upon this margin we can walk pretty commodiously. The whole of it is covered with burnt sand, under which we find stones partly natural and partly calcined. . . . . In two elevations on this margin, we find beds of natural stones arranged in the same manner as in other mountains; which confutes the notion of those who regard Vesuvius as a mountain gradually raised above the plain of the valley. . . . .

" The depth of the gulf where the matter boils

is about 543 feet; and the height of the mountain above the level of the sea is 1,677 feet, which is one third of an Italian mile.

"This height has been more considerable. The eruptions which have changed the external form of the mountain, have likewise diminished its elevation; for the parts they detached from the summit rolled into the gulf*."

From all these examples, if we consider the external figure of Sicily and other countries ravaged by fire, we shall evidently perceive that no volcano exists which is purely isolated or detached. The surface of these countries every where presents a succession, and sometimes groups of volcanos. This we have already seen with regard to Ætna, and shall give a second example of it in Hecla. A great part of the island, like Sicily, is only a group of volcanos, which I shall prove by the following observations:

The whole island ought to be regarded as a vast mountain interspersed with deep cavities, concealing in its bowels great quantities of minerals, vitrified and bituminous substances, and rising from the midst of the sea in the form of a short flattened cone. Its surface presents to the eye nothing but tops of mountains covered with snow and ice; and lower down we have the picture of confusion and ruin. It is an enormous mass of stones and fragments of rocks, which are sometimes porous and half calcined, and exhibit a

* Hist. du Mont Vesuve, par le P. de la Torré; Journal Etranger, Janvier, 1756, p. 182—208.

hideous appearance by their blackness and the marks of fire impressed upon them. The fissures and hollows of rocks are filled with a red, and sometimes with a black or white sand: but, in the valleys between the mountains, we find agreeable plains *.

Most of Jokuts, which are mountains of a middle height, and overtopped by others of a greater elevation, are volcanos, that occasionally throw out flames, and produce earthquakes: of these there are no less than twenty in this island. The inhabitants in the neighbourhood of these mountains have learned, by experience and observation, that, when the ice and snow rise to a considerable height, and stop the mouths of these cavities, which formerly discharged flames, earthquakes are about to happen, which are always succeeded by cruptions of fire. It is for this reason that the Icelanders are at present afraid lest the Jokuts, which, in the year 1728, threw out flames in the canton of Skaftfield, should soon be again inflamed; the ice and snow being accumulated on their summits, and appearing to obstruct those vents which favoured the exhalations of the subterraneous fires.

In 1721, the Jokut called Koëtlegau, about five or six leagues to the west of the sea, near the bay of Portland, broke out into flames, after several succussions of the earth. This conflagration melted masses of ice of an enormous thickness, and gave rise to impetuous torrents, which de-

* Introd. a l'Hist du Danemark.

luged the country, and carried down to the sea prodigious quantities of earth, sand, and stones. The solid masses of ice, and the immense quantity of earth, stones, and sand, transported by the inundation, so loaded the sea, that, at half a mile from the coast, a small mountain was formed, which still appeared above the sea in the year 1750. We may form some idea of the quantity of matter carried down to the sea by this inundation, when we consider that it was obliged to retreat twelve miles beyond its former limits.

The inundation continued three days; and it was not till after this period that a person could pass on foot to the mountains. . . . . .

Hecla, which has always been regarded as one of the most famous volcanos in the universe, on account of its tremendous eruptions, is now one of the least dangerous in the island. Mounts Koëtlegan and Krafle have recently made as great ravages as Hecla did of old. It has been remarked, that this last volcano has thrown out flames ten times only in the space of 800 years, namely, in the years 1104, 1157, 1222, 1300, 1341, 1362, 1389, 1558, 1636, and, lastly, in the year 1693. This eruption commenced on the 13th of February, and continued to the month of August following. All the other eruptions lasted a few months only. From the above dates it appears, that Hecla made its greatest ravages in the fourteenth century, having undergone no less than four eruptions; that it remained perfectly tranquil during the fifteenth century; and that it

threw out no fire for 160 years. From this period, there was one eruption only in the sixteenth, and two in the seventeenth century. We now perceive in this volcano neither fire, nor smoke, nor exhalations of any kind. We only find, in some small hollows, as is common in many other parts of the island, boiling water, stones, sand, and ashes.

In 1726, after a few successions of the earth, which were felt only in the northern cantons, Mount Krafle began to throw out, with a dreadful noise, smoke, flames, ashes, and stones. This eruption continued two or three years, without doing any damage; because the whole rejected matter fell back upon the mountain, or round its base.

In 1728, the fire communicated with some mountains situated near Krafle, which burnt during several weeks. When the minerals they contained were melted, a river of fire ran gently toward the south into the country below these mountains. This river threw itself into a lake about three leagues from Mount Krafle, and, by the shock of the water, produced a horrible noise, and clouds of vapours. The running of the lava did not cease till 1729, when the matter which formed it was probably exhausted. The lake was filled with an immense quantity of calcined stones, which raised its water considerably. It is about twenty leagues in circumference, and situated at an equal distance from the sea. We shall not take notice of the other

volcanos in this island; it is sufficient that we have mentioned the most considerable of them *.

From this description we perceive that the Jokuts of Hecla greatly resemble the secondary volcanos of Ætna: that, in both, the highest summit is tranquil; that the summit of Vesuvius is much sunk; and that probably those of Ætna and Hecla were formerly higher than they are at present.

Though the topography of volcanos in other parts of the world is not so well known as that of those in Europe, we may, nevertheless, presume, from analogy, and the similarity of their effects, that they resemble each other in every respect. They are all situated in islands, or upon the coasts of continents. Almost the whole of them are surrounded with secondary volcanos. Some of them are active, and others extinguished or quiet. The number of the latter is greater, even in the Cordeliers, which appear to be the most ancient domain of volcanos. In the south of Asia, the islands of Sonde, the Moluccas, and Philippines, bear evident marks of destruction by fire, and are still infested with volcanos. They are likewise very frequent in the island of Japan: this country is also more subject to earthquakes than any other part of the globe. In many places of Japan there are hot fountains. Most of the Indian islands, and all the seas of these eastern regions, present to our eyes nothing but peaks and detached sum-

* Hist. Gen. des Voyages, tom. xviii. p. 9--11.

mits, which vomit out fire, and deep indented coasts, the relics of ancient continents which are now no more. Here the mariner often meets with ports which daily sink; and even whole islands have been known to disappear, and to be swallowed up, with their volcanos, by the waters. The seas in China are warm, *which is a proof* that there is a great effervescence in the maritime basins of this region. The hurricanes are tremendous, and water spouts are frequent. The tempests are always preceded by general and perceptible boilings of the waters, and by various meteors and other exhalations, with which the atmosphere is loaded.

The volcano of Teneriffe has been explored by Dr. Thomas Heberden, who resided several years in the village of Oratava, which is situated at the foot of the Peak. In his way, he found large stones disposed on all sides at several leagues from the top of the mountain. Some of them appeared to be entire, and others seemed to have been burnt, and thrown to this distance by the volcano. In ascending the mountain, he still saw burnt rocks scattered about in large masses.

"We arrived," Dr. Heberden remarks, "at the famous grotto of *Zegds*, which is surrounded on all sides with enormous masses of burnt rocks. . . . .

"A quarter of a league higher, we met with a sandy plain, in the middle of which there is a pyramid of sand or yellowish ashes, called

the Sugar Loaf. Round its base, fuliginous vapours perpetually arise. From thence to the summit, the distance might be half a quarter of a league. But the ascent is too difficult on account of its steepness and the bad footing. . . .

" However, we reached what is called the Cauldron, which is twelve or fifteen feet deep. Its sides taper to the bottom, and form a cavity, which resembles a reversed cone. . . . . Here the ground is very warm; and, from about twenty tubes or chimneys, a thick sulphureous vapour arises. The whole ground seems to be mixed with sulphur, which gives the surface a brilliant appearance. . . .

" Upon almost all the stones in the neighbourhood, we perceive a greenish colour, intermixed with yellow, like gold. A small part of this sugar loaf is as white as chalk, and another part, still lower, resembles red clay covered with salt. . . .

" In the middle of another rock we discovered a hole, which exceeded not two inches in diameter, from whence proceeded a noise similar to that of a considerable quantity of water boiling over a great fire *."

The Azores, the Canaries, the islands of Cape Verd, Ascension Island, and the Antilles, which appear to be the relics of ancient continents that united the Old Continent with America, offer nothing to our observation but burnt lands, or lands which still continue to burn. The vol-

* Observations on the Peak of Teneriffe by Dr. Heberden.

canos formerly sunk under the waters with the countries which supported them, excite such terrible tempests, that, in one of these storms, which happened at the Azores, the suet fixed to the end of the plumb-line melted by the heat at the bottom of the sea.

In Asia, and particularly in the islands of the Indian Ocean, volcanos are numerous. One of the most famous is Mount Albours, near Mount Taurus, about eight leagues from Herat. The top of this mountain sends forth a perpetual smoke; and it frequently throws out flames and burning matter in such quantities as to cover all the adjacent plains with ashes. In the island of Ternate, there is a volcano which discharges matter similar to pumice stones. Some voyagers allege, that this volcano is most furious during the equinoxes, because these periods are attended with certain winds which increase the inflammation of those fires that have continued to burn for ages *. The island of Ternate is not above seven leagues round, and is only the top of a large mountain. The land rises from the coast to the middle of the island, where the volcano mounts to a height so great, that it is difficult to climb to its top. Several rills of sweet water descend from the sides of the mountain; and, when the air is calm, and the weather fine, this burning gulf is less agitated than during storms and high winds †. This is a confirmation of what

* See Voyages d'Argensola, tom. i. p. 21.
† See Voyage de Schouten.

I formerly remarked, and seems to prove, that the fire of volcanos proceeds not from a great depth, but from the top or higher parts of the mountain; for, if it were otherwise, high winds could not increase the violence of the flames.

There are other volcanos in the Molucca islands. In one of the islands of Mauritius, about seventy leagues from the Moluccas, there is a volcano, the effects of which are equally violent as those of the mountain at Ternate. The island of Sorea, one of the Moluccas, was formerly inhabited. In the middle of this island there is a very high mountain, with a volcano at its summit. In 1693, this volcano discharged an immense quantity of bitumen and inflamed matter, which, after forming a burning lake, gradually extended till it covered the whole island *.

There are several volcanos in Japan, and the adjacent islands, which send out flames in the night, and smoke in the day. In the Philippine islands, there are likewise several burning mountains. One of the most remarkable, and, at the same time, the most recent volcano in the Indian islands, is that near the town of Penarucan in the island of Java. It commenced in the year 1586, and, at the first eruption, it threw out immense quantities of sulphur, bitumen, and stones. The same year, Mount Gounapi, in the island of Banda, which had been a volcano about seventeen years only, opened and ejected, with a dreadful noise, rocks, and matter of every

* See Phil. Trans. abridg. vol. ii. p. 391.

kind. There are still other volcanos in India, as in Sumatra, and in the north of Asia, beyond the river Jenisca, and the river Pesida: but the two last are little known.

Near Fez in Africa, there is a mountain, or rather a cavern, called Beni-guazeval, which constantly throws out smoke, and sometimes flame. One of the Cape de Verd islands, called the island of Fuogo, is nothing but a huge mountain, which burns incessantly. This volcano throws out stones and ashes; and the Portuguese, who often attempted to inhabit the island, have always abandoned the project, on account of the volcano. The Peak of Teneriffe, which is reckoned one of the highest mountains in the world, throws out fire, ashes, and large stones From the top of it, rivulets of melted sulphur run down the south side across the snows. This sulphur soon condenses, and forms veins in the snow, which are distinguishable at great distances.

America, and particularly the mountains of Mexico and Peru, are much infested with volcanos: that of Arequipa is one of the most celebrated: it often produces great earthquakes, which are more frequent in Peru than in any country of the world. Next to Arequipa, the volcanos of Carrappa and Malahallo are, according to the relation of travellers, the most considerable. But there are many others in the New World of which we have no knowledge. M. Bouguer, in his voyage to Peru, published in the Memoirs of the Academy for the year 1744, mentions two volcanos, the one called Cotopaxi,

and the other Pichincha. The first is at some distance from, and the other very near, the town of Quito. In the year 1742, he saw an eruption of Cotopaxi, which, at that time, burst open a new mouth in the mountain. It did no other damage than that of melting the snow, and producing such torrents, as, in three hours, laid the whole country, to the extent of eighteen leagues, under water, and overturned every thing in their course.

Popochampeche and Popocatapec are the chief volcanos in Mexico. It was near this last that Cortes passed in his way to the city of Mexico: some of the Spaniards ascended to the top of the mountain, where they found the crater to be about half a league in circumference. Sulphureous mountains have also been found in Guadaloupe, Tercera, and in others of the Azore islands; and, if all the mountains from which smoke or flames issue were to be considered as volcanos, their number would exceed sixty. We have only mentioned those which are so formidable, as, by their frequent eruptions, to prevent people from living near them.

The numerous volcanos in the Cordeliers, as I formerly remarked, produce almost perpetual earthquakes, which prevent the inhabitants from building with stone any higher than the first floor; and the upper parts of their houses, for the same reason, are constructed with rushes or very light wood. In these mountains there are also many precipices and large gulfs, the walls of which are black and burnt: they are similar to

the precipice of Mount Ararat in Armenia, called the Abyss, and are the craters of extinguished volcanos.

A late earthquake at Lima was attended with the most dreadful effects. The town of Lima, and the port of Callao, were almost entirely swallowed up. But the mischief was still more terrible at Callao. The sea rose and covered every house in that unfortunate town, and drowned the whole inhabitants, leaving only a single tower as a monument of its devastations. Of twenty-five vessels which lay in the harbour, four were driven a league upon land, and the rest were swallowed up by the waves. Of Lima, which was a very large city, only twenty-seven houses remained standing. Multitudes of people perished; and the disaster was particularly fatal to the monks and other religious, because their buildings were lofty and of more solid materials than the common houses. This calamity happened in the month of October, 1746, during the night; and the succussion lasted fifteen minutes.

Near the port of Pisca, in Peru, there was formerly a famous city, situated on the sea-coast; but, on the 19th of October, 1682, it was almost entirely destroyed by an earthquake; for the sea, having exceeded its usual limits, sweeped away this unfortunate city, with all its inhabitants.

By consulting historians and travellers, we shall find many accounts of earthquakes and eruptions of volcanos, equally dreadful and destructive as those we have mentioned. Posi-

donius, quoted by Strabo *, relates, that a city of Phœnicia, near Sidon, was swallowed up by an earthquake, with the neighbouring territory, and two thirds of Sidon itself; that this effect was not produced so suddenly as to prevent the inhabitants from escaping by flight; that it extended over most of Syria, and as far as the Cyclades islands and Eubœa, where the fountains of Arethusa suddenly stopped, and appeared a few days afterwards by new sources, at a considerable distance from the old; and that the earthquake continued to shake the island, sometimes in one place, and sometimes in another, till the earth opened in the valley of Lepanta, and discharged a great quantity of burning matter. Pliny informs us †, that, in the reign of Tiberius, twelve cities in Asia were overturned; and he mentions ‡, in the following terms, a prodigy occasioned by a violent earthquake. "Factum est semel (quod equidem in Etruscæ disciplinæ voluminibus inveni) ingens terrarum portentum, Lucio Marco, Sex. Julio Coss. in agro Mutinensi. Namque montes duo inter se concurrerunt, crepitu maximo adsultantes recedentesque, intor eos flamma, fumoque in cœlum exeunte interdiu, spectante e via Æmilia magna equitum Romanorum familiarumque et viatorum multitudine. Eo concursu villæ omnes elisæ, animalia permulta, quæ intra fuerunt, exanimata sunt," &c. St. Augustin tells

* Lib. i. † Lib. i. c. 84 ‡ Lib. ii. c. 83.

us *, that, in Lybia, 100 towns were destroyed by an earthquake. In the time of Trajan, the earth opened and devoured the city of Antioch, and a great part of the adjacent country. It was again destroyed by the same cause during the reign of Justinian, in the year 528, and 40,000 of its inhabitants perished. It was visited with a third earthquake in the days of St. Gregory, sixty years after the former, which destroyed no less than 60,000 of its inhabitants. In the reign of Saladin, *anno* 1182, most of the cities of Syria and of Judæa were laid waste by the same calamity. Earthquakes have been more frequent in Apulia and Calabria than in any other part of Europe. In the time of Pope Pius II. all the churches and palaces of Naples were thrown down, and about 30,000 lives were lost: those who escaped were obliged to live in tents till houses were built for them. In 1629, 7,000 persons perished in Apulia by earthquakes; and, in 1638, the city of Saint Euphemia was swallowed up, and left behind it nothing but a stinking lake: at the same time, Ragusa and Smyrna were almost totally destroyed. In 1692, an earthquake was felt in Britain, Holland, Flanders, Germany, and France: it was most severe along the coasts of the sea, and near great rivers. It agitated at least 2,600 square leagues, though it lasted but two minutes. The commotion was greater in the mountains than in the val-

* Lib. ii. de Miraculis, c. 3

leys*. On the 10th of July, 1688, there was an earthquake at Smyrna, which began with a motion from west to east. The castle was first overturned; its four walls separated from each other, and sunk six feet in the sea. This castle stood formerly on an isthmus, which is now a real island, about 100 paces from the land. The east and west walls fell; but the north and south walls still remain. The city, which is near ten miles from the castle, was overthrown soon after. The earth opened in many places, attended with subterraneous noises; and five or six dreadful shocks were felt before the approach of night, the last of which lasted about half a minute. The ships in the roads were greatly agitated; the ground on which the town stood sunk two feet; and not above a fourth of the houses withstood the concussion, and those were mostly founded on rock. From fifteen to twenty thousand lives were lost †. In 1695, an earthquake was felt at Bologna in Italy; and it was remarked, as a singular phænomenon, that the sea was much troubled the day preceding ‡.

"On the 4th of May, 1614, a terrible earthquake happened at Tercera, which, beside private houses, overturned eleven churches and nine chapels in the city of Angra; and the city of Praya was so much shaken, that hardly a house was left standing: and, on the 15th of June, 1628, the island of St. Michael was visited with

* See Ray's Discourses, p. 272.

† See l'Hist. de l'Acad. des Sciences, ann. 1688.

‡ Ibid. ann. 1696.

a great earthquake. Near this island, in the open sea, there arose a new island in a place where the water was 150 fathoms deep. This island was more than a league and a half long, and above six fathoms high *.

" In the island of St. Michael, another earthquake began on the 26th of July, 1691, and continued to the 12th of the following month. Tercera and Fayal were shaken next day with such violence, that they seemed to turn about. These concussions, however, were repeated there only four times: but, at St. Michael, they ceased not a moment during the space of eleven days. The islanders abandoned their houses, which every where tumbled down before their eyes, and remained the whole time in the open fields, exposed to the injuries of the weather. The whole town of Villa Franca was overturned to the foundation, and most of the inhabitants were buried under its ruins. In several places, the plains were elevated into hills, and, in others, the hills sunk down into valleys. A fountain of fresh water issued from the ground, and ran for four days, and then stopped all of a sudden. The air and the sea were in such commotion, that they made a noise resembling the bellowings of ferocious animals. Many people died of fear. There was not a vessel in the harbours which was not agitated in a dangerous manner; and those which lay at anchor, or were under sail, at the distance of twenty leagues, were still more se-

* See Mandelslo's Voyages.

verely tossed. Earthquakes are very frequent in the Azores: twenty years before the period mentioned, a mountain in St. Michael was overturned by a dreadful earthquake *.

"In the month of September, 1627, an earthquake levelled one of the two mountains of Manilla, called Carvalos, in the province of Cagayon. In 1645, a third part of the city was destroyed by a similar accident, and 300 persons perished in the ruins. The following year it was visited by another; and the old Indians tell us, that earthquakes are now less destructive than formerly; but they still build their houses of wood, in which they are imitated by the Spaniards.

"The number of volcanos in this island confirms the above relation; for, at certain intervals, they vomit forth flames, shake the earth, and produce all the effects ascribed by Pliny to the eruptions of Vesuvius, such as changing the beds of rivers, making the neighbouring parts of the sea retreat, covering the places adjacent with ashes, projecting stones to great distances, and making reports louder than those of cannons †."

"In 1646, an earthquake split a mountain in the island of Machian, and the explosion made a frightful noise. From the cleft issued such a quantity of flames as consumed several plantations with their inhabitants. This prodigious aperture was to be seen in the year 1685, and it

* Gen. Hist. of Voyages, vol. i. p. 325.

† See Voyage de Gemelli Careri, p. 129.

probably remains to this day. It was called the Wheel-track of Machian, because it ran from the top to the bottom of the mountain, and, at a distance, had the appearance of a high road *."

The History of the French Academy mentions, in the following terms, the earthquakes which happened in Italy during the years 1702 and 1703. "They began in October, 1702, and continued till July, 1703. The city of Norcia, with its dependencies in the Ecclesiastical State, and the province of Abruzzo, suffered most; and the earthquakes were first felt in those places which are situated at the foot of the Appennines, on the south side.

"They were frequently accompanied with frightful noises in the air, and these noises were sometimes heard when the earth was at rest, and the sky serene. The most violent concussion was on the 2d of February, 1703; and it was attended, especially at Rome, with a remarkable clear sky, and a great calmness in the air. At Rome it lasted half a minute, and at Aquila, the capital of Abruzzo, three hours. Beside ravaging the neighbouring country, it destroyed the whole town of Aquila, and buried 5,000 persons under its ruins.

"The concussions, or vibrations, of the earth, as was discovered by the motion of the lamps in the churches, were nearly from south to north.

"The earth opened in two places, and discharged, with violence, great quantities of stones,

* See l'Hist. de la Conquête des Moluques, tom. iii. p. 318.

which covered a whole field, and rendered it barren. After the stones, these apertures threw up water above the elevation of the highest trees. This discharge continued a quarter of an hour, and laid the neighbouring country under water. The water was whitish, like soap-suds, and had no particular taste.

"On the top of a mountain near Sigillo, a village about twenty-two miles from Aquila, there was a considerable plain, surrounded with rocks like a wall. The earthquake of the 2d of February converted this plain into a large unequal gulf, its greatest diameter being twenty-five fathoms, and its least twenty. This gulf has been sounded with ropes of 300 fathoms, without reaching the bottom. At the time that the gulf was formed, flames were observed to issue out of the mountain, and afterwards a thick smoke, which continued, with some interruption, for three days.

"At Genoa, they had two slight concussions on the 1st and 2d days of July, 1703, the last of which was only felt by the people on the Mole. The sea, at the same time, sunk six feet in the port, and continued in this situation a quarter of an hour.

"The sulphureous water on the road between Rome and Tivoli sunk two feet and a half, both in the basin and in the canal. The springs and rills of water, which rendered many places of the plain called Testine marshy, were entirely dried up. The depth of the water in the lake called l'Enfer was diminished three feet In

place of the old springs, new ones, about a mile distant, appeared: they are probably the same waters, the courses of which have been changed by the concussion of the earth *."

The same earthquake, which, in 1538, formed the Monti de Cinere, near Puzzoli, filled the Lucrine Lake with stones, earth, and ashes, and converted it into a marsh †.

"Earthquakes, also," says Mr. Shaw, "have sometimes been felt at sea. In the year 1724, when I was aboard the Gazella, an Algerine cruiser of fifty guns, bound to Bona to relieve the garrison, we felt three prodigious shocks, one after another, as if a weight, at each time, of twenty or thirty ton, had fallen from a great height upon the ballast. This happened when we were five leagues to the southward of the Seven Capes, and could not reach ground with a line of 200 fathoms. The captain told me, that, a few years before, when he was upon a cruise, he felt a much greater one, at the distance of forty leagues to the westward of the rock of Lisbon ‡."

Schouten, speaking of an earthquake which happened in the Moluccas, says, "that the mountains were shaken, and that the vessels at anchor in thirty or forty fathom water were shocked, as if they had run ashore, or struck against rocks. We learn," continues he, "from daily experience, that the same happens in the ocean, where

* See l'Hist. de l'Acad. des Sciences, ann. 1704.
† See Ray's Discourses, p. 12. ‡ Shaw's Travels, p. 151.

no bottom can be found; and that earthquakes agitate vessels, even when the sea is perfectly calm *."

Gentil, in his voyage round the world, has the following remarks upon earthquakes:

" 1. That half an hour before the earth begins to shake, all animals appear to be seized with a panic. The horses neigh, break their halters, and run out of the stable; the dogs bark; the birds, as if stupid, fly for shelter into the houses; the rats and mice come out of their holes, &c.

' 2. That ships at anchor are so violently agitated, that all the parts of which they are composed seem to be torn asunder; their guns break loose, and their masts spring: these facts I should hardly have credited, if they had not been confirmed to me by the unanimous testimony of many witnesses. I know that the bottom of the sea is a continuation of the land; and that agitations of the one must be communicated to the other; but I could not comprehend how the different parts of a vessel, swimming in a fluid, should be affected in the same manner as if she had been resting on the ground. Her motion, I imagined, should have only resembled that produced by a storm; besides, in the present instance, the surface of the sea was smooth, and the whole agitation must have proceeded from some internal cause, because, at the time of the earthquake, there was no wind

* Voyages, vol. vi. p 103

"3. That if the cavern of the earth, which contains the subterraneous fire, runs from north to south, and if the buildings of a town above it lie in the same direction, the whole houses are overturned; but, if the vein or cavern runs across the town, the damage produced by the earthquake is less considerable*."

When a new volcano breaks out in countries subject to earthquakes, they almost entirely cease, and are seldom felt, except during great eruptions, as has been observed with regard to the island of St. Christopher†.

The enormous ravages produced by earthquakes have induced some naturalists to imagine, that mountains, and all the other irregularities on the surface of the globe, have derived their origin from succussions of the earth occasioned by the action of subterraneous fires. This, for instance, is the opinion of Mr. Ray. He believes that all the mountains have been formed by earthquakes, or by the explosions of volcanos, in the same manner as Monti de Cinere in Italy, the new island near Santorini, &c. But he has not considered that the small elevations formed by earthquakes, or by the eruptions of volcanos, are not, like all other mountains, composed of horizontal strata; for, by digging into the Monti de Cinere, we find calcined stones, ashes, burnt earth, iron dross, pumice stones, all blended together like a heap of rubbish. Besides, if earth-

* See Voyage de M. le Gentil, tom. i. p. 172.

† See Phil. Trans. abridg. vol. ii. p. 392.

quakes and subterraneous fires had raised the great mountains of the earth, as the Cordeliers, Mount Taurus, the Alps, &c., the prodigious force requisite to elevate these enormous masses would, at the same time, have destroyed a great part of the surface of the globe. Earthquakes sufficient to produce such effects must have been inconceivably violent, since the greatest of them recorded in history have not been able to produce a single mountain. In the reign of Valentinian I., for instance, an earthquake was felt over the whole known world *, and yet it raised not a single mountain.

It is capable of demonstration, however, that though an earthquake should have a force sufficient to raise the highest mountains, this force would not be able to displace the rest of the globe.

For, let it be supposed, that the chain of high mountains which traverses South America from the point of Terra Magellanica to New Granada and the gulf of Darien, had been suddenly elevated by an earthquake, and then let us estimate the effect of this explosion. This chain of mountains is about 1,700 leagues long, and, at a medium, forty leagues broad, including the Sierres, which are lower than the Andes. This gives a surface of 68,000 square leagues. The thickness of the matter displaced by the earthquake I suppose to be one league; or, that the

* Ammian. Marcellin lib. xxvi. c. 14.

mean height of the mountains from their summits to the caverns, which, agreeable to this hypothesis, must support them, is one league. The force of the explosion, therefore, must have elevated, to the height of a league, a quantity of earth equal to 68,000 cubic leagues. But, action and reaction being equal, this explosion must have communicated an equal quantity of motion to the whole globe. Now, the whole globe consists of 12,310,523,801 cubic leagues. From this number take 68,000, and there remains 12,310,455,801 cubic leagues, of which the quantity of motion would be equal to that of 68,000 elevated one league. Hence it appears, that the force necessary to raise 68,000 cubic leagues would not be sufficient to displace the whole globe a single inch.

There is no absolute impossibility, therefore, in the supposition, that the mountains have been raised by earthquakes, were it not evident, both from their internal structure and their external figure, that they have been formed by the operation of the waters of the ocean. Their interior parts are composed of parallel strata, interspersed with sea shells; and their external figure consists of angles every where corresponding. Is it credible that this uniform structure, and regular figure, could have been produced by sudden and desultory succussions of the earth?

But, as this notion has been embraced by some philosophers, and as the nature and effects of earthquakes are not well understood, I shall

hazard a few ideas, which may, perhaps, throw some light upon this intricate subject.

The surface of the earth has undergone many changes. At considerable depths, we find holes, caverns, subterraneous rivulets, and voids, which sometimes communicate with each other by means of chinks and fissures. There are two species of caverns: the first are those which have been formed by volcanos and the action of subterraneous fires. The action of subterraneous fire elevates, shakes, and throws off to a distance the superincumbent materials; at the same time, it splits and deranges those on each side of it, and thus produces caverns, grottos, and irregular hollows. But such effects are only exhibited in the neighbourhood of volcanos, and are not so frequent as the other species of caverns, which are produced by the operation of water. It has already been remarked, that the different strata of the earth are all interrupted by perpendicular fissures, the origin of which shall be afterwards explained. The waters which fall upon the surface descend through those fissures, collect when their progress is prevented by a stratum of clay, and form springs and rivulets. From the nature of water, it searches for cavities or small vacuities, and has a constant tendency to force a passage, till it finds a proper vent. Wherever it goes, it carries along with it sand, gravel, and other bodies which it is capable of dividing or dissolving. In this manner, the operation of water proceeds till it forms subterraneous passages; and then it breaks out in the

form of fountains, either on the surface of the earth, or in the bottom of the sea. The materials it perpetually carries off leave hollows or caverns in the bowels of the earth, which are often of great extent; and these caverns have a very different origin from those produced by volcanos or earthquakes.

Earthquakes are of two kinds: those occasioned by the action of subterraneous fires, and by the explosions of volcanos, are only felt at small distances, previous to, or during the time of eruptions. When the inflammable matters in the bowels of the earth begin to ferment and to burn, the fire makes an effort to escape in every direction; and if it finds no natural vents, it forces a passage, by elevating and throwing off the incumbent earth. In this manner volcanos commence, and their effects continue in proportion to the quantity of inflammable matter they contain. When the quantity of inflamed matter is inconsiderable, it produces only an earthquake, and exhibits no marks of a volcano: the air generated by subterraneous fire may also escape through small fissures; and, in this case, likewise, it will be attended with a succussion of the earth; but no volcano will appear. But when the quantity of inflamed matter is great, and when it is confined on all sides by solid and compact bodies, an earthquake and a volcano are the necessary consequences. All these commotions, however, constitute only the first species of earthquakes, which are not felt but in the neighbourhood of the places where they happen.

A violent eruption of Ætna, for example, will shake all the island of Sicily; but it will never extend to the distance of 300 or 400 leagues. When Vesuvius bursts open a new mouth, it excites an earthquake in Naples and in the neighbourhood of the volcano; but these earthquakes never shake the Alps, nor do they extend to France, or other countries distant from Vesuvius. Thus earthquakes, produced by volcanos, are limited to a small place; they are nothing but effects of the reaction of the fire, and they shake the earth in the same manner as the explosion of a powder-magazine occasions an agitation to the distance of several leagues.

But there is another species of earthquakes, which are very different in their effects, and perhaps also in their cause. These earthquakes are felt at great distances, and shake a long tract of ground without the intervention either of a new volcano, or of eruptions in those which already exist. There are instances of earthquakes which have been felt at the same time in Britain, in France, in Germany, and in Hungary. These earthquakes always extend more in length than in breadth. They shake a zone or belt of earth with greater or less violence in different places; and they are generally accompanied with a hollow noise, like that of a heavy carriage rolling with rapidity.

As to the causes of this species of earthquake, it must be remarked, that the explosion of all inflammable substances, like that of gunpowder, generates a great quantity of air; that this air,

is highly rarefied by heat; and that its effects, from the compression it receives by being confined in the bowels of the earth, must be exceedingly violent. Let us suppose, that, at the depth of 100 or 200 fathoms, there is a vast collection of pyrites and sulphureous bodies, and that they are inflamed by the fermentation produced by the admission of water to them, or by other causes. What must be the effect? In the first place, these substances are not placed in horizontal beds, like the ancient strata, which were formed by the sediments of the waters. They are lodged, on the contrary, in the perpendicular fissures, in subterraneous caverns, and other places, to which the water has access. When inflamed, they generate a vast quantity of air, the spring of which, by being compressed within a small space, like that of a cavern, will not shake the earth immediately above, but it will search for passages, in order to expand and make its escape. Caverns and channels of subterraneous rivulets and springs, are the only natural passages for this rarefied air. Into these, therefore, it will rush with impetuosity, and produce in them a furious wind, the noise of which will be heard on the surface; and it will be attended with vibrations or succussions of the ground. This subterraneous wind produced by fire will extend the whole length of the caverns or channels, and occasion a shaking, more or less violent, in proportion to its distance from the heat, and to the width or narrowness of the canals. But this motion must necessarily

run in a longitudinal direction; and the shaking, of course, must be felt over a long belt of ground. This air, however, cannot produce an eruption or a volcano; because it finds sufficient room for expanding itself, and diminishing its force, or, rather, because it escapes through fissures in the form of vapour or of wind. But, although the existence of caverns or channels for the passage of this rarefied air should be denied, it is easy to conceive that, in the very place where the explosion is made, as the earth is elevated to a considerable height, the neighbouring places must split horizontally in attempting to yield to the impulse communicated by the original motion; and, in this manner, passages may be gradually and successively opened, so as to communicate with very distant places. This explication corresponds with all the phænomena. Earthquakes are not felt at great distances at the same minute, or even the same hour. They are not accompanied with eruptions, or external fire; and the noise almost constantly marks the progressive motion of the subterraneous wind. Other facts concur in establishing this theory. Blasts of wind, and vapours, sometimes of a suffocating nature, it is well known, arise from mines, independent of the motion of the air produced by the current of water. It is equally well known, that winds issue from certain apertures of the earth, from caverns, abysses, and deep lakes, as Lake Boleslaw in Bohemia, which has been formerly mentioned.

Earthquakes are produced by two causes:

the first is the sudden sinking of cavities in the bowels of the earth; and the second, which is still more frequent and more violent than the first, is the action of subterraneous fires.

When a cavern sinks in the middle of a continent, it produces a commotion which extends to a greater or smaller distance, in proportion to the quantity of motion excited by the fall of this mass of earth; and, if this mass is inconsiderable, or falls from no great height, it will not produce a succussion so violent as to be perceived at a great distance; the effect is limited to the neighbourhood of the sunk cavern; and if the movement is propagated to greater distances, it is only by slight tremblings or vibrations.

As most of the primitive mountains rest upon caverns, because, at the moment of their consolidation, these eminences were blown up by the action of the internal fire, sinkings in the mountains have happened, and still happen, whenever the vaults of the caverns are undermined by water, or shaken by any convulsion. An entire portion of a mountain sometimes sinks perpendicularly, but oftener inclines, and not unfrequently reverses. Of this we have striking examples in several of the Pyrennees, where the strata, formerly horizontal, are often inclined more than forty-five degrees; which shows, that the entire mass of each portion of the mountain, whose strata were parallel to each other, has inclined by the lump, and, in the moment of its sinking, rested upon a base inclined to the horizon forty-five degrees. This

is the most general cause of the inclination of strata in mountains. For the same reason we often find, between the adjacent eminences, strata which descend from the first and rise to the second, after having traversed the valley. These strata are horizontal, and are bedded at the same height in the two opposite hills, between which the cavern had fallen in. The earth sinks down; and the valley is formed, without producing any other derangement than a greater or smaller inclination of the strata, according to the depth of the valley, or the declivity of the two opposite hills.

This is the only sensible effect of the sinking of caverns in mountains and other parts of continents. But whenever this effect happens in the bottom of the sea, where sinkings must be more frequent than on the land, because the water perpetually undermines the vaults in every place where they support the bottom of the ocean, these sinkings not only derange and incline the strata, but sensibly lower the level of the sea. From the first occupation of the waters, their level has been depressed 2,000 fathoms by these sinkings; and, as all the submarine caverns have not yet fallen in, it is more than probable, that the basin of the sea, by growing more and more deep, will lessen its surface, and, of course, that the extent of all the continent will always continue to augment by the retreat and sinking of the waters.

A second and more powerful cause than the first concurs in producing the same effect. This

cause is the rupture and sinking of caverns by the action of submarine fires. It is certain, that no motion or sinking in the bottom of the sea can happen without diminishing its surface: and, if we consider the general effects of subterraneous fires, we will perceive that, as long as there is fire, the commotions of the earth will not be confined to simple tremblings; for the efforts of fire raise and open the sea and the land by violent and reiterated succussions, which not only overturn and destroy the adjacent lands, but shake those that are distant, and ravage or derange every thing in the route of their direction.

The earthquakes occasioned by subterraneous fires generally precede eruptions of volcanos, and sometimes cease the moment the fire opens a passage through the earth, and carries its flames into the air. These dreadful earthquakes sometimes continue during the whole time of eruptions. These two effects are intimately connected. There is never a great eruption of a volcano without being preceded, or at least accompanied, with an earthquake. But we often feel very violent succussions of the earth without any eruption of fire. Those movements, in which fire has no part, proceed not only from the first cause, the falling in of caverns, but likewise from the action of subterraneous winds and storms. There are many examples of lands raised or sunk by the force of these internal winds. Sir William Hamilton, a man as respectable for his private character as admirable for the extent

of his knowledge and researches on this subject, told me, that he had seen, between Trente and Verona, near the village of Roveredo, several little hills composed of large masses of calcarious stones, which had evidently been raised by different explosions of subterraneous winds. There is no indication of the action of fire upon any of these rocks or their fragments. The whole country, on both sides of the highway, for an extent of near a league, has, from place to place, been overturned by the prodigious efforts of subterraneous winds: the inhabitants say that it happened suddenly, and was the effect of an earthquake.

But the force of the wind, however violent, appears not to be a cause sufficient to produce such great effects; and, though there be no marks of fire in these little hills, raised by the commotion of the earth, I am persuaded that they have been elevated by electrical explosions of subterraneous thunder, and that the internal winds have contributed to this effect solely by producing electrical storms in the cavities of the earth. Hence all convulsive movements of the earth may be referred to three causes: the first and most simple is the sinking of caverns; the second, storms and subterraneous thunder; and the third, the action of fire kindled in the interior parts of the globe. It is easy to ascribe to one or other of these three causes all the phænomena which accompany or succeed earthquakes.

Commotions of the earth sometimes give rise

to eminences; but they more frequently produce gulfs. On the 15th day of October, 1773, a gulf opened in the territory of Induno, in the state of Modena, the cavity of which was more than 400 fathoms wide by 200 deep*. In 1726, a mountain of a considerable height, situated in the northern part of Iceland, was sunk in one night by an earthquake, and a very deep lake assumed its place. The same night, about a league and a half distant, an ancient lake, the depth of which was unknown, was entirely dried up, and its bottom raised in such a manner as to form a pretty high hill, which still exists †. In the seas in the neighbourhood of New Britain, M. Bougainville remarks, earthquakes have terrible effects on navigation. On the 17th of June, the 12th and 27th of July, 1768, there were three earthquakes at Boero, and, on the 22d of the same month, one at New Brittany. These earthquakes sometimes annihilate islands and known sand-banks, and sometimes create them ‡.

There are earthquakes which extend to great distances; but they are always longer than broad. One of the most considerable was that felt in Canada, in the year 1663. It extended more than 200 leagues in length and 100 in breadth, *i. e.* more than 20,000 superficial leagues. The effects of the last earthquake in Portugal, which happened in our own time, were felt still farther.

* Journ. Hist. et Politique, Dec. 10, 1773, art. Milan.

† Melanges interassans, tom. i. p. 159.

‡ Voyage autour du Monde, tom. ii. p. 278.

M. le Chevalier de Saint-Sauveur, king's commandant at Merucis, informed M. de Gensanne, that, when walking on the left margin of Jouante, in Languedoc, the sky suddenly became very dark, and that, in a moment after, he perceived, at the foot of the hill, which is situated to the right of that river, a terrible bright globe of fire: immediately there arose from the bowels of the earth a considerable mass of rocks, and the whole chain of mountains split from Merucis to Florac, an extent of near six leagues. This rent, in some places, is more than two feet wide, and has partly fallen in *. There are other earthquakes which produce little or no commotion. Kolbe relates, that, on the 24th of September, 1707, from eight to ten o'clock before noon, the sea rose upon the land at the Cape of Good Hope, and descended seven times successively, and with such rapidity, that, from one moment to another, the place was alternately covered and left by the waters †.

With regard to the effects of earthquakes, the falling of mountains, and the sinking of caverns, I shall subjoin a few facts, which are both recent and well attested. In Norway, a whole promontory, called Hammersfields, suddenly fell ‡. A very high mountain near that

* Hist. Nat. de Languedoc, par M. de Gensanne, tom. i. p. 231.

† Descript. du Cap de Bonne-Esperance, tom. ii. p. 237.

‡ Hist. Nat. de Norwége, Pontoppidan; Journal Etranger, Août, 1755.

of Chimboraço, one of the highest of the Cordeliers, in the province of Quito, tumbled down in a moment. This fact, with all its circumstances, is related in the Memoirs of M. de la Condamine and Bouguer. Similar fallings and sinkings often happen in the southern islands of India. At Gamma-canore, where the Dutch have a settlement, a high mountain fell suddenly in the year 1673, when the weather was fine: it was followed by an earthquake, which overturned the neighbouring villages, and destroyed several thousands of persons *. On the 11th of August, 1772, in the island of Java and province of Cheribou, one of the richest settlements of the Dutch, a mountain, of about three leagues in circumference, suddenly sunk, and rose and sunk alternately like waves in a stormy ocean: it at the same time threw out many globes of fire, which were seen at a great distance, and gave a light as brilliant as that of day: all the plantations, together with about 2,140 inhabitants, without reckoning strangers, were entirely swallowed up †. We might recite many other examples of the sinking of lands and swallowing of mountains by the rupture of caverns, and the succussions occasioned by earthquakes and the action of volcanos: but we have said enough to establish the general conclusions we have drawn from the facts already related.

* Hist. Gen. des Voyages, tom. xvii. p. 54.

† See Gazette de France, 21 Maii, 1773, art. de la Haie.

When these remarks are considered, I cannot comprehend how the mountains should have originated from earthquakes, since the mineral and sulphureous bodies which occasion them are seldom to be met with but in the perpendicular fissures of mountains, and in other cavities of the earth, the greatest number of which have been produced by the operation of water; since these inflammable substances produce only a momentary explosion, and violent winds, which follow the channels of subterraneous waters; since the duration of earthquakes on the surface of the earth is so short, they must be occasioned by a sudden explosion, and not by a continued conflagration; and, *lastly*, since those earthquakes, which extend over large tracts of ground, never produce the smallest eminence throughout their whole course.

Earthquakes, it is true, are more frequent in the neighbourhood of volcanos, as in Sicily, and the environs of Vesuvius: but it appears, from repeated observations, that these earthquakes are very limited, and, consequently, can never form a chain of mountains.

It has sometimes been remarked, that the matters ejected from Ætna, after cooling for several years, and being afterwards moistened with rain, have rekindled, and thrown out flames with such violent explosions, as to occasion small earthquakes.

In 1669, during a violent eruption of Ætna, which began on the 11th of March, the summit

of the mountain sunk considerably *; which is a proof that this volcano proceeds rather from the superior part of the mountain than from the bottom of it. Borelli, who is of the same opinion, observes, "that the fire of a volcano proceeds neither from the centre, nor from the bottom of a mountain, but from the top; and that the inflammation never kindles but at a small depth †."

Mount Vesuvius has frequently thrown out, during eruptions, great quantities of boiling water. Mr. Ray, who imagines that the fire of volcanos comes from a very great depth, says, that this water proceeds from the sea, which communicates, by subterraneous passages, with the foot of the mountain. As a proof, he mentions the remarkable dryness of the top of Vesuvius, and the agitation of the sea during eruptions, which sometimes recedes so far as to leave the port of Naples entirely dry. But, supposing these facts to be true, they by no means prove that the fire of volcanos proceeds from a great depth; for the water they eject is certainly rain-water, which penetrates through the fissures, and collects in the cavities of the mountain. Rills and springs issue from the tops of volcanos, as well as from other high mountains; and, as the former are hollow, and have suffered more concussions than the latter, nothing can be more

* See Phil. Trans. abridg. vol. ii. p. 387.

† Borelli de incendiis Montis Ætnæ.

natural than that they should collect water in their caverns, and that this water should sometimes be ejected, along with other substances, in the time of eruptions. With regard to the motion of the sea, it arises solely from the shock communicated to the waters by the explosion, which makes them advance or retire according to different circumstances.

The most common substances thrown out by volcanos are torrents of melted minerals, which overflow the environs of the mountain. These rivers of lava extend to great distances; and, in cooling, they form beds, either horizontal or inclined, in the same manner as the strata accumulated by successive sediments from water. But the former are easily distinguishable from the latter: 1. Because strata of lava are not every where equal in thickness. 2. Because they contain nothing that has not evidently been calcined, vitrified, or melted. 3. Because their extent is more limited. As there is a vast number of volcanos in Peru, and as the bottoms of most of the Cordeliers are covered with substances which have been thrown out by eruptions, it is not surprising that no sea shells have been found there; for they must have been calcined and destroyed by the fire. But I am still persuaded, that, if the clay ground, which, according to M. Bourguet, is the ordinary earth in the valley of Quito, had been dug, shells would have been discovered there, as well as every where else, especially where the ground is not covered, like the bot-

toms of the mountains, with matters ejected from volcanos.

It has often been asked, Why all volcanos appear in high mountains only? I have partly solved this question in the preceding article. But, before finishing the present subject, I shall endeavour more fully to explain myself.

The peaks or points of mountains were originally covered with earth and sand, which, after being gradually washed down to the valleys by the rains, left nothing but those bare rocks or stones called the core of mountains, which, being likewise subjected to the action of the weather, small and large fragments of them must have been occasionally loosened, and, of course, must have rolled down to the plains. The rocks at the base of the summit being fully uncovered, and having lost their original support from the sand and earth, would necessarily give way a little, and, by separating from each other, would produce small intervals. But this yielding of the lower rocks could not take place without rending those which lay above them. In this manner the core of the mountain, from the summit to the base of the lower rocks, would be split into an infinite number of perpendicular fissures of different dimensions. Through these the rains would penetrate, and carry along with them, into the bowels of the mountain, all the minerals, and other substances which they were capable of transporting or dissolving. Here pyrites, sulphur, and other combustible substances, would be

produced; and, in the course of time, these bodies would accumulate in great quantities, and, by their fermentation, would give rise to explosions, and other effects of volcanos. Heaps of these mineral substances might likewise exist in the heart of the mountain, before the rain could penetrate so deep. In this case, as soon as the air or rain got access to them by means of the perpendicular fissures, a conflagration and volcano would instantly take place. No such phænomena can be exhibited in plains; for, as every thing there is at rest, and nothing can be displaced, it is not surprising that the existence of volcanos should be confined entirely to the mountains.

When coal mines are opened, which are commonly found in clay grounds, and at a great depth, the mineral substances above mentioned sometimes kindle into flames. There are examples in Scotland, Flanders, &c., of coal mines which have continued to burn for many years. The admission of air is alone sufficient to produce this effect. But these inflammations occasion only slight explosions, and never form volcanos; because, in such places, all being plain and solid, the fire cannot be excited to such a degree as in burning mountains, which are full of caverns and cliffs, through which the air penetrates, and augments the action of the fire so forcibly, as to give rise to the terrible effects we have been describing.

Of extinguished Volcanos.

The number of extinguished volcanos exceeds incomparably that of those which are active. They are very numerous in almost every part of the earth. I might mention those remarked by M. de la Condamine in the Cordeliers, and by M. Frenaye in St. Domingo *, near Port-au-Prince, and those of Japan and the other eastern and southern islands of Asia, the whole of which countries have been formerly ravaged by fire. But I shall limit myself to the extinguished volcanos of the isles of France and Bourbon, which have been recognised by some enlightened voyagers.

"The soil of the isle of France," says M. l'Abbé de la Caille, "is covered with a prodigious number of stones of all sizes, which are of a blackish ash colour. Many of them are full of holes, like a sieve. Most of them contain a great quantity of iron; and the surface of the earth is covered with the ore of this metal. We likewise find, especially on the north coast of the island, a great many pumice stones, lavas, or refuse of iron, profound grottos, and other manifest vestiges of extinguished volcanos. . . .

"The isle of Bourbon," continues M. l'Abbé de la Caille, "though larger than the isle of France, is only a large mountain, split as it were from its summit into three different parts. Its

* Note communicated to M. de Buffon, by M. Frenaye, March 10, 1777.

top is covered with wood, and inhabited; and two thirds of its declivity, which extends as far as the sea, are cleared and cultivated. The rest is covered with the lavas of a volcano, which burns slowly and without any noise. It seems not to burn much, except during the rainy seasons. . . .

"Ascension Island has visibly been formed and burnt by a volcano. It is covered with a red earth, similar to brick-dust or burnt clay. . . . . The island is composed of several mountains from 100 to 150 fathoms high. There is one still larger to the south of the island, which is about 400 fathoms in height. . . . . Its summit is double and lengthened: but all the others are pretty perfect cones, and covered with red earth. The land and part of the mountains are interspersed with prodigious quantities of rocks full of holes, like sieves, and with very light calcarious stones, a number of which resembled coagulated milk; some of them were laid over with a dirty white varnish, approaching to green. Pumice stones are likewise very frequent*."

The celebrated captain Cook remarks, that, in an excursion to the interior parts of Otaheite, they found burnt rocks, like those of Madeira; that all the stones bore incontestible marks of fire; that they likewise perceived traces of fire in the clay upon the hills; and that Otaheite and a number of adjacent islands might be supposed to be the relics of a continent which had been swal-

* Mem. de l'Acad. des Sciences, ann. 1754, pp. 111, 121, and 126.

lowed by the explosions of subterraneous fire*. Philip Carteret tells us, that one of the Charlotte islands, situated in the 11° 10′ of south latitude, is of a prodigious height and a conical figure; that its summit is like a funnel, from which smoke issues, but no flames; and that, on the most southern coast of New Britain, there are three mountains, from one of which proceeds a large column of smoke*.

We find basalts in the isle of Bourbon, where the volcano, though feeble, still acts: in the isle of France, where all the fires are extinct; and in Madagascar, where there are both active and extinguished volcanos. But, to mention no other basalts but those of Europe, we know that there are considerable masses of them in Ireland, in Britain, in Auvergne, upon the borders of the Elbe, in Misnia upon Mount Cattener, at Marienburg, at Weilbourg in the county of Nassau, at Lauterback, at Billstein, in several parts of Hesse, in Lusace, in Bohemia, &c. These basalts are most beautiful lavas, produced, in all these countries, by volcanos which are now extinct But we shall content ourselves with abridged descriptions of extinguished volcanos in France.

"The mountains of Auvergne," says M. Guettard, "which have formerly, in my estimation, been volcanos. . . . are those of Volvic, two leagues from Riom; of Puy-de-dôme, near Clermont; and of Mount Or: The volcano of Vol-

* Cook's Voyage, tom. ii. p. 431.

† Carteret's Voyage, pp. 250 and 27

vic has formed, by its different lavas, strata lying upon each other, and composing enormous masses, in which quarries are dug, and furnish stones to several places at a distance. . . . . . It was at Moulins where I first discovered lava; . . . . and being at Volvic, I perceived that the mountain was almost entirely composed of matters which had been thrown out by the eruptions of volcanos.

"The figure of this mountain is conical, and its base consists of rocks of a grayish white granite, or of the colour of a pale rose. . . . . The rest of the mountain is composed entirely of blackish or reddish pumice stones, heaped upon each other without order or connexion. . . . About two thirds up the mountain, we meet with irregular rocks, bristled with misshapen points turned to all sides, and of an obscure red or dirty black. They are solid and hard, and have no holes like the pumice stones. . . . . Before arriving at the summit, we find a hole of some fathoms wide, and of a conical figure, approaching to that of a funnel. . . . . The part of the mountain to the north and east, appeared to be solely composed of pumice stones. . . . . In Volvic, the beds of stone follow the inclination of the mountain, and seem to be continued through it, and to communicate with those discovered by the ravines a little below the summit . . . . These stones are of an iron-gray colour, and seem to have a white grain, which comes out on the surface like an efflorescence: though spongy, and full of small irregular holes, they are hard.

"Mount Puy-de-dôme is nothing but a mass

of matter which indicates the dreadful effects of the most violent fire. . . . . In those places of the mountain which are not covered with plants and trees, we travel among pumice stones, pieces of lava, and a gravel or sand, formed by a kind of iron dross and small bits of pumice stones mixed with ashes.

"These mountains exhibit several peaks, and all of them have cavities or funnels of greater or smaller dimensions. One of these peaks, the road which leads to it, and the whole space as far as Puy-de-dôme, are only vast heaps of pumice stones. The same observation is applicable to the other peaks, which are fifteen or sixteen in number, situated in the same line from south to north, and all of them furnished with funnels.

"The top of the peak of Mount Or is a rock composed of a tender whitish ash-coloured stone, similar to that on the summits of all the mountains in this volcanic country: it is only a little lighter than that of Puy-de-dôme.

"If I found not on this mountain as many vestiges of a volcano as in the other two, it must be partly ascribed to this circumstance, that Mount Or is more covered, through its whole extent, with trees and shrubs, than Mounts Volvic and Puy-de-dôme. . . . . However, the south-east part is entirely bare, and entirely composed of stones and rocks, which seem to have been exempted from the effects of the fire. . . . .

"But the peak of Mount Or is a cone similar to those of Volvic and Puy-de-dôme. To the

east of this point is the Peak du Capuchin, which is likewise conical, but not so regular as those of the preceding mountains. It even appears that this peak has undergone more changes in its structure; for every thing is more irregular, and broken into smaller portions. . . . There are still several other peaks, the bases of which rest upon the ridge of the mountain; but they are all overtopped by Mount Or, which is 509 fathoms high. . . . The peak of Mount Or is very rugged: it terminates in a point about fifteen or twenty feet in diameter. . . . . .

"There are several conical mountains between Thiers and Saint Chaumont, which led me to think," says M. Guettard, "that they might have been burnt. . . . Though I have never been at Pontgibault, I have sufficient proofs to convince me that the mountains of this canton are extinguished volcanos; I have received fragments of lava from them, which it was easy to recognise by the yellow and blackish points of vitrified matter, which are the most certain characteristics of volcanic productions *."

The same M. Guettard and M. Faujas have found, on the left bank of the Rhone, and a good way into the country, very large fragments of basaltic columns. . . . In ascending into the Vivarais, they found in a rapid brook a vast collection of volcanic matter, which they followed to its source. It was not difficult to recognise the volcano. It is a very high moun-

* Mem. de l'Acad. des Sciences, ann. 1752, p. 27—58.

tain, on the top of which they found a mouth of about eighty feet in diameter. Below this mouth the lava is partly visible. It has flowed down the ravines, in great masses, for the space of seven or eight thousand fathoms. The matter has heaped together while yet burning in certain places: and, after fixing, it chapped and split through its whole thickness, and left the plain entirely covered with innumerable columns, from fifteen to thirty feet long by about seven inches in diameter*.

"Having proceeded to Montferrier," says M. Montet, "a village about a league distant from Montpelier. . . . . . I found a number of black stones, detached from each other, and of different figures and sizes. . . . I compared them with others, which were unquestionably the production of volcanos. . . . . and found them to be of the same nature. Hence I no longer doubted that these stones of Montferrier were a very hard lava, or a matter melted by a volcano, which had long been extinguished. The whole mountain of Montferrier is interspersed with these stones, and the streets are paved and the village partly built with them. . . . . The surfaces of these stones are, in general, full of holes or porosities, which sufficiently indicate that they have been formed of matter melted by a volcano. This lava is dispersed over all the grounds adjacent to Montferrier. . . . .

* Journal de Physiques, par M. l'Abbé Rozier; mois de Decembre, 1775, p. 516.

" On the side of Pézenas, extinguished volcanos are very numerous. . . . . The whole country is full of them, especially from Cap d'Agde, which itself is an extinguished volcano, to the foot of that chain of mountains that commences five leagues to the north of this coast, and upon their declivity, or at a little distance from them, are situated the villages of Livran, Peret, Fontés, Néfiez, Gabian, and Faugéres. In going from south to north, we find a remarkable plinth or chaplet, which begins at Cap d'Agde, and comprehends Mount Saint Thibery and Causse (mountains situated in the middle of the plains of Bressan), the peak of Valros in the territory of this village, the peak of Montredon in the territory of Tourbes, and that of Saint Marthe, near the royal priory of Cassan. Besides, from the foot of the mountain, a great and long mass arises, and terminates to the south near the Granges of Prés, and from east to west between the village of Caus and that of Nizas. . . . . It is to be remarked of this canton, that it consists of almost nothing but a mass of lava, and that in the middle of it there is a round mouth, or distinct crater, about 200 fathoms in diameter, which formed a pond that has since been drained by a deep cut through the hard lava, which is disposed into strata, or rather contiguous undulations. . . . .

" In all these places we find lava and pumice stones. Almost the whole village of Pézenas

is paved with lava. The rock of Agde is nothing but a hard lava, and the whole of this village is built and paved with this lava, which is very black. . . . . Almost the whole territory of Gabian, in which is the famous fountain of Petroleum, is bestrewed with lava and pumice stones.

"We likewise find at Causse, Basan, and Saint Thibery, a considerable quantity of basalts, which are commonly prisms with six sides, and from ten to fourteen feet in length. These basalts are found in a place where the vestiges of an ancient volcano are no longer recognisable.

"The baths of Balaruc every where present us with relics of an extinguished volcano. The stones found there are nothing but pumices of different sizes. . . . .

"In all the volcanos I examined, I remarked that the matter or stones thrown out are of various figures. Some of them are in large, heavy, and hard masses, like the rock of Agde: others, like those of Montferrier and the lava of Tourbes, are in detached pieces, of considerable weight and hardness *."

M. Villet, of the academy of Marseilles, has transmitted to the king's cabinet some specimens of lava and other matters found in the extinguished volcanos of Provence; and he writes me, that, a league from Toulon, there are evi-

* Mem. de l'Acad. des Sciences, ann. 1760, p. 466-473.

dent vestiges of an ancient volcano; and that, having descended a ravine to the foot of this old volcano of Mount d'Ollioules, he was struck with the appearance of a detached rock which had come down from the mountain. It was calcined; and, having broke off some pieces, he found in the heart some sulphureous particles, so strongly marked, that he no longer doubted the ancient existence of these volcanos, which are now extinct *.

M. Valmont de Bomare has observed, in the territory of Cologne, the vestiges of several extinguished volcanos.

I could give many other examples, which all concur in proving, that the number of extinguished volcanos is perhaps a hundred times greater than of those now actually existing. I must here remark, that, between these two, there are, as in all the other operations of Nature, intermediate states, degrees, and shades, of which we can only lay hold of the principal traits. For example, the Solfataras are neither active nor extinguished volcanos, but seem to participate of both. These no man has better described than one of our learned academicians, M. Fougeroux de Bondaroy; I shall, therefore, lay before the reader his chief observations:

" Solfatara, situated four miles west from Naples, and two miles from the sea, is surrounded

* Lettre de M. Villet a M. de Buffon; Marseille, le 8 Mai, 1775.

on all sides with mountains. Before arriving at it, we must ascend about half an hour. The space comprised between the mountains forms a basin of about 1,200 feet in length by 800 feet broad. With regard to the mountains, it lies in a bottom; but it is not so low as the ground you traverse in going to it. The soil in the bottom of the basin is a very fine, close, beaten sand, and it is so dry and parched, that it produces no vegetables. The colour of the sand is yellowish. . . . . . The sulphur, which is found in great quantities among the sand, gives it this colour. The mountains, which bound the greatest part of the basin, consist of bare rocks, without earth or plants. Some of them are split, and their parts are burnt and calcined; but the whole present no arrangement or order in their position. . . . . . They are covered with greater or smaller quantities of sulphur, which is sublimed in this part of the mountain and in the neighbouring basin.

"The opposite side consists of a better soil. . . . . . Neither does it present furnaces similar to those formerly mentioned, and which are common on the other side.

"In several places, we find, in the bottom of the basin, apertures or mouths, from which issue smoke, accompanied with a heat that would burn the hands smartly; but it is not strong enough to kindle paper. . . . . .

"The adjacent places produce a heat which is felt through the shoes, and a disagreeable odour of sulphur exhales from them. . . . . . When a

sharp pointed stick is thrust into the ground, there soon issues a vapour or smoke, similar to that which exhales from the natural crevices.

"Through these apertures a small quantity of sulphur is sublimed, together with a salt which has all the characters of sal ammoniac.

"On several stones which surround Solfatara. we find threads of alum. . . . . Lastly, sulphur is collected from Solfatara. . . . This substance is extracted from grayish stones, interspersed with shining particles, which are sulphur crystallized between the stony particles. . . . These stones are sometimes impregnated with alum.

"By striking the middle of the basin with our foot, we easily perceive that the ground is hollow below.

"If we traverse the side of the mountain, where the mines are most numerous, we find lavas, pumice stones, the dross of volcanos, &c. In a word, the whole appearances, when compared with the matters at present furnished by Vesuvius, demonstrate that Solfatara was formerly the mouth of a volcano. . . . .

"The basin of Solfatara has often changed its form; and we may conjecture that it will still assume others. This territory daily hollows and undermines itself. It at present forms a vault which covers an abyss. . . . If this vault sinks, the abyss will probably fill with water, and produce a lake.*"

M. Fougeroux de Bonderoy has likewise made

* Mem. de l'Acad. des Sciences, ann 1765, p. 267—283.

some observations on Solfataras in other parts of Italy.

"I have been," says he, "at the source of a rivulet, which we pass in the road between Rome and Tivoli, the water of which has a strong odour of liver of sulphur. . . . . It forms two small lakes, about forty fathoms in their greatest extent. . . . .

"One of these lakes, according to the plumb-line we were obliged to use, was, in different places, sixty, seventy, and eighty fathoms deep. In these lakes we saw several floating islands, which sometimes change their situation. . . . . They are composed of plants reduced into a kind of light turf, upon which the waters, though corrosive, have no effect. . . . .

"The heat of these waters was twenty degrees, when the thermometer in the open air stood at eighteen degrees. Thus it appears, from experiment, that the heat of these waters is inconsiderable. . . . . They exhale a disagreeable odour; and this vapour changes the colour of vegetables and of copper *."

"The Solfatara of Viterbe," M. l'Abbé Mazeas remarks, "has a mouth of from three to four feet only. Its waters boil, exhale an odour of the liver of sulphur, and petrify their canals, like those of Tivoli. . . . . The degree of their heat is that of boiling water, and sometimes more. . . . The volumes of smoke, which sometimes arise, indicate a still greater heat; and yet the bottom

* Mem. de l'Acad. des Sciences, ann. 1770, p. 1—7.

of the basin is covered with plants, which grow in the bottom of the lakes, and in the marshes. In ferruginous soils, these waters produce vitriol, &c. * "

" In several of the Appennine mountains, and particularly in those on the road from Bologna to Florence, we find fires, or vapours which require only the approach of a candle to inflame them. . . . .

" The fires of Mount Cenida, near Pietramala, are situated at different heights of the mountain, upon which we find four mouths that throw out flames. . . . . One of these fires is in a circular place surrounded with a rising ground. . . . . Here the earth appears to be burnt, and the stones are blacker than those in the neighbourhood; there likewise issues, here and there, a lively, blue, clear flame, which rises from three to four feet high. . . . . But, beyond this circular space, we see no fire, though the heat of the ground is perceptible at the distance of sixty feet from the centre of these flames. . . . .

" Along a fissure or crevice in the neighbourhood of the fire, we hear a dull noise, like that of wind moving through a subterraneous passage. Near this place, we find two sources of hot water. . . . . The ground, in which fire has long existed, is neither depressed nor elevated. . . . . Near this fire we see no volcanic stones, nor any mark which indicates that fire has ever been

* Mem. des Savans Etrangers, tom. v. p. 325.

thrown out. However, some little hills in the neighbourhood have every appearance of having been formed, or at least changed by volcanos. . . . . In 1767, succussions of an earthquake were felt in the environs; but no change was produced on the fire, neither was the smoke increased or diminished.

"About ten leagues from Modena, at a place called Barrigazzo, there are five or six openings, where, at particular times, flames appear, which are extinguished by a strong wind: there are likewise vapours which inflame by contact with fire. . . . . But, notwithstanding the unequivocal vestiges of extinguished volcanos, which subsist in most of these mountains, the fires seen there are not new volcanos forming, because they never throw out any volcanic matter *."

Hot waters, as well as the fountains of Petroleum, and other bituminous and oily substances, should be regarded as another shade between extinguished and active volcanos. When subterraneous fires exist near strata of coal, they dissolve the coal, and give rise to most sources of bitumen: they likewise occasion the heat of the hot springs which run in their neighbourhood. But these subterraneous fires now burn with tranquillity; and we only recognise their ancient explosions by the substances they have formerly rejected. They ceased to act when the sea re-

* Mem. sur le Pétrole, par M. Fougeroux de Banderoy, dans ceux de l'Acad. des Sciences, ann. 1770, p. 45.

tired from them; and, as already remarked, I believe there is no longer any reason to dread the return of these direful explosions, since every observation concurs in showing that the sea will always retire farther and farther.

Of Lavas and Basalts.

To what we have said on the subject of volcanos, we shall add some remarks on the motion of lavas, and on the time necessary for their cooling and their conversion into vegetable soil.

The lava which runs from the foot of the eminences formed by the matters rejected by the volcano, is an impure glass in fusion. It is a tenacious, viscous, and half fluid substance. Hence the torrents of the vitrified matter, when compared to torrents of water, run slowly; and yet they often proceed to great distances. In these torrents of fire, however, there is another movement than what takes place in those of water: this movement tends to elevate the whole running mass, and is produced by the expansive force of the heat in the interior parts of the burning torrent. The external surface cools first; the liquid fire continues to run below; and, as heat acts equally on all sides, the fire, which endeavours to escape, elevates the superior parts that are already consolidated, and often forces them to rise perpendicularly. This is the origin of those large masses of lava in the form

of rocks, which are found in the course of almost every torrent where the declivity is not great. *By* the efforts of this internal heat, the lava makes frequent explosions; its surface opens, and the liquid matter springs up and forms those masses which we see elevated above the level of the torrent. Le P. de la Torré, I believe, is the first person who observed this internal movement of burning lavas, which is always more violent in proportion to their thickness and the gentleness of the declivity. This effect is common to all matters liquified by fire, and every man may see examples of it in our common founderies *. If we observe those large ingots or masses of melted iron, which run in a mould or canal with a very small declivity, we shall perceive that they have a tendency to rise like arches, especially when the stream is very thick †. We have

* The lava of iron founderies exhibits the same effects. When this vitreous matter runs slowly, and accumulates at the base, we see eminences arise, which are bubbles or concave hemispheres of glass. These bubbles increase, when the expansive force is great, and the matter has little fluidity: it then suddenly explodes into a flame, and makes a considerable report. When the liquified matter is sufficiently adhesive to suffer a great dilatation, these superficial bubbles acquire a volume of eight or ten inches in diameter, without breaking. When the vitrification is less complete, and the matter is viscous and tenacious, the bubbles are smaller, and in cooling form concave eminences, called *toads' eyes*. What happens in miniature in our founderies, is likewise exhibited upon a larger scale in the lavas of volcanos.

† I have not mentioned some particular causes which frequently produce a curvature or swelling in our melted ingots: for example, when the matter is not very fluid, or when the

formerly shown, by experiments, that the time of consolidation is always proportioned to the thickness of the ingots, and that, when their surfaces are hardened, the interior parts still continue to be liquid. It is this internal heat which elevates the ingots and makes them blister. If their thickness were greater, there would be produced, as in the torrents of lava, explosions, ruptures in the surface, and perpendicular jets of metallic matter, pushed out by the action of the fire inclosed in the interior parts of the ingots. This explication, drawn from the nature of the thing itself, leaves no doubt concerning the origin of those eminences so frequent in valleys and plains, which have been overrun or covered with lava.

When, after descending from the mountain and traversing the fields, the burning lava arrives at the margin of the sea, its course is suddenly interrupted, the torrent advances, and, like a powerful enemy, makes the water at first retire: but the water by its immensity, by the resistance of its cold, and by its power of arresting and extinguishing fire, soon consolidates the torrent of burning matter, which can now proceed no farther, but rises up, accumulates new strata, and forms a perpendicular wall,

mould is too moist, the ingots bend considerably; because these causes concur in augmenting the effect of the first. Thus the humidity of the ground, on which the torrents of lava descend, and the internal heat, concur in raising the mass, and in producing explosions, which are always accompanied with those jets of matter formerly mentioned.

from the top of which the lava falls, and applies itself to the face of the wall thus formed. It is this falling and arresting of the burning matter that gives rise to basaltic prisms * and their jointed columns. These prisms have generally five, six, or seven sides, sometimes only three or four, and sometimes eight or nine. The basaltic columns are formed by the perpendicular fall of the lava into the sea, whether it falls from high rocks on the shore, or from a wall raised by its own accumulations. In both cases, the cold and humidity of the water arrest the burning matter, and consolidate its surfaces the moment it falls; and the successive bundles or masses of lava apply themselves to each other. As the internal heat of these masses tends to dilate them, a reciprocal resistance is created; and the same effect is produced as happens in the swelling of pease, or rather of cylindrical grain, when squeezed in a close vessel filled with boiling water. Each of these grains would assume a hexagonal figure by reciprocal compression. In the same manner, each bundle or mass of lava assumes several sides by dilatation and reciprocal resistance; and, when the resistance of the surrounding bundles is stronger than the dilatation of the bundle surrounded, instead of becoming hexagonal, it has only three, four, or five sides.

* I shall not here inquire into the origin of the term *basalt*, which M. Desmarets, of the Academy of Sciences, a learned naturalist, believes to have been applied by the ancients to different kinds of stones; but shall limit myself to the *basaltic lava*, which appears under the form of prismatic columns.

But, if the dilatation of the surrounded bundle is stronger than the resistance of the surrounding bundles, it assumes seven, eight, or nine sides, which are always longitudinal.

The transverse articulations of these prismatic columns are produced by a cause still more simple: the bundles of lava fall not in a regular and continued stream, nor in equal masses. Hence, if there are intervals in the fall of the matter, the superior surface of the forming column, being partly consolidated, is hollowed by the weight of the succeeding mass, which then moulds itself into a convex form in the concavity or depression of the first. This is the productive cause of those joints or articulations which appear in the greater part of prismatic columns. But, when the lava falls in an uninterrupted stream, then the basaltic column is one continued mass, without any articulations. In the same manner, when, by an explosion, some detached masses are darted from the torrent of lava, these masses assume a globular or elliptical figure, and are even sometimes twisted like cables. To this simple explication, all the forms of basalts and figured lavas may be easily referred.

It is to the rencounter of lava with the waves, and its sudden consolidation, that the origin of these bold coasts, which border all the seas at the foot of volcanic mountains, is to be ascribed. The ancient ramparts of basalt, found in the interior parts of continents, show that the sea has

been in the neighbourhood of these volcanos when they had thrown out lava. This is an additional proof of the ancient abode of the waters upon all the lands now inhabited.

The torrents of lava are from 100 to 2,000 and 3,000 fathoms broad, and sometimes 150, and even 200 feet thick: and, as we have found, by experience, that the time of the cooling of glass is to that of the cooling of iron as 132 to 236, and that the times of their respective consolidation are nearly in the same proportion, it is easy to infer, that, to consolidate the thickness of ten feet of glass or lava, $201\frac{21}{59}$ minutes would be necessary, since it requires 360 minutes to consolidate ten feet thick of iron, consequently it will require 4,028 minutes, or sixty-seven hours eight minutes, to consolidate 200 feet thick of lava: by the same rule, we shall find, that $30\frac{17}{24}$ days, or a month, will be requisite before the surface of this lava of 200 feet thick be sufficiently cold to admit of being touched. Hence a year will be necessary to cool a lava of 200 feet thick, so as to admit of being touched, without burning, at the depth of one foot; and, at ten feet deep, it will be still so warm, at the end of ten years, as not to be tangible; and 100 will be requisite to cool it to the same degree in the middle of its thickness. Mr. Brydone relates, that, more than four years after the lava had flowed, in the year 1766, at the foot of Ætna, it was not perfectly cool. Massa, a Sicilian author worthy of credit, tells us, " that,

being at Catania, eight years after the great eruption in 1669, he found, that the lava in several places was not entirely cool*."

About the end of April, 1771, sir William Hamilton dropt pieces of dry wood into a crevice in the lava at Vesuvius, and they were instantly inflamed: the lava issued from the mountain on the 19th of October, 1767, and had no communication with the fire of the volcano. The place where this experiment was made was at least four miles distant from the mouth from which the lava issued. He is firmly persuaded, that many years are necessary to cool a lava of this thickness (about 200 feet).

I have had no opportunity of making experiments upon consolidation and cooling, but with balls of some inches in diameter. The only method of making experiments on a larger scale would be, to observe lavas, and to compare the times exhausted in their consolidation and cooling, according to their different thicknesses. I am satisfied that these observations would confirm the law I have established for the cooling of bodies from the state of fusion to the common temperature; and, although these new observations are by no means necessary to support my theory, still they would help to fill up that immense gap between a cannon ball and a planet.

It now remains for us to examine the nature of lava, and to show, that, in time, it is con-

* Voyage au Sicile, tom. i. p. 213.

verted into fertile earth; which recalls the idea of the first conversion of the scoriæ of the primitive glass that covered the whole surface of the globe after its consolidation.

"Under the denomination of lava, we comprehend not," says M. de la Condamine, "all the matter thrown out by a volcano, such as ashes, pumice stones, gravel, and sand; but solely those reduced to a liquid state by the action of fire, and which, by cooling, form solid masses, whose hardness surpasses that of marble. This restriction notwithstanding, many other species of lava may be conceived, according to the different degrees of fusion in the mixture, the greater or smaller quantity of metal, and its greater or lesser intimate union with the various matters. Beside many intermediate kinds, three species are easily distinguishable. The purest lava resembles, when polished, a stone of an obscure dirty gray colour. It is smooth, hard, heavy, and interspersed with small particles similar to black marble, and whitish points. It seems to contain metallic particles. At first sight, it resembles serpentine, when the colour of the lava does not tend to green. It receives a pretty fine polish, which is more or less vivid in different parts. It is made into tables, chimney-pieces, &c.

"The coarsest kind of lava is rugged and uneven. It resembles the scoriæ or dross of iron. The most common species holds a middle rank between the two extremes: it is that which we every where find in large masses upon the sides

of Vesuvius and in the adjacent fields where it has run in torrents. In cooling, it has formed masses similar to ferruginous and rusty rocks, which are often many feet thick. These masses are frequently interrupted and covered with ashes and calcined matter. . . . . . It is under several alternate strata of lava, ashes, and earth, the whole of which forms a crust of from sixty to eighty feet thick, that temples, porticos, statues, a theatre, and an entire city have been discovered*."

M. Fougeroux de Bondaroy remarks, "that, immediately after an eruption of burnt earth or of a kind of ashes, Vesuvius generally throws out lava, which runs down the fissures or furrows made in the mountain. . . . .

"The mineral matter inflamed, melted, and flowing, or lava, properly so called, issues through cracks or crevices with more or less impetuosity, and in greater or smaller quantity, according to the violence of the eruption. It spreads to a greater or smaller distance, according to the degree of fluidity, and the declivity of the mountain, which more or less retards its cooling. . . . .

"That which now covers a part of the land at the foot of the mountain, and which sometimes stretches as far as Portici, consists of large heavy masses, bristled with points on their upper surface. The surface which rests on the ground is flatter: as these pieces lie above

* Mem. de l'Acad. des Sciences, ann. 1757, p. 374.

each other, they have some resemblance to the waves of the sea. When the pieces are larger and more numerous, they assume the figure of rocks. . . . .

"In cooling, the lava effects various forms. . . . The most common is that of tables or boards, of greater or smaller dimensions. Some pieces are six, seven, and eight feet long. It breaks into this form in cooling and consolidating. This is the species of lava which is bristled with points. . . . . .

"The second species resembles great ropes: it is always found near the mouth of the volcano, and appears to have been suddenly fixed, and to have rolled before it hardened. It is lighter, more brittle, more bituminous, and softer, than the first species. By breaking it, we likewise perceive that its substance is not so close and compact. . . .

"At the top of the mountain, we find a third species of lava, which is brilliant, and composed of threads, which sometimes cross one another. It is coarse, and of a reddish violet colour. . . . . Some fragments are sonorous, and have the figure of stalactites. . . . . . Lastly, in certain parts of the mountain, we find lavas of a spherical form, and appear to have been rolled. It is easy to conceive how the figures of these lavas might be varied by a number of accidental circumstances*," &c.

Matter of every kind enters the composition

* Mem. de l'Acad. des Sciences, ann. 1766, p. 75.

of lavas. Iron and a small quantity of copper have been extracted from the lava found on the summit of Vesuvius. Some specimens are so impregnated with metallic substances as to preserve the flexibility of metal. I have seen two large tables of lava, of two inches thick, which were polished like marble, and bended with their own weight. I have seen others, which were bended by a weight, and resumed their horizontal position by their own elasticity.

All lavas, when reduced to powder, are, like glass, susceptible of being converted, by the intervention of water, first into clay, and afterwards, by the mixture of dust and corrupted vegetables, into excellent soil. These facts are apparent from the vast and beautiful forests which surround Ætna, and grow upon a bottom of lava, covered with several feet of good earth: the ashes are more quickly converted into earth than the powder of glass or of lava. In the craters of old extinguished volcanos, as well as on the ancient rivers of lava, we find very fertile soils. Hence the devastations occasioned by volcanos are limited by time; and, as Nature is always more disposed to produce than to destroy, she, in a few ages, repairs the devastations of fire, and restores to the earth its former fertility by the very same materials she had employed for the purposes of destruction.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE XVII.

Of new Islands, Caverns, perpendicular Fissures, &c.

NEW islands are formed in two ways, either suddenly, by the operation of subterraneous fires, or slowly, by the accumulated sediments of water. Upon this subject we are furnished with indubitable facts, both by ancient historians, and by modern voyagers. Seneca tells us, that, in his time, the island of Therasia * suddenly emerged from the sea, to the astonishment of many spectators. Pliny relates, that thirteen islands formerly arose all at once from the bottom of the Mediterranean, and that Rhodes and Delos are the chief of them. According to Ammianus, Marcellinus, Philo, Pliny, &c., these thirteen islands were not formed by an earthquake or by a subterraneous explosion, but were formerly concealed under the water, which sunk and un-

* Now called Santorini.

covered them. Delos was even distinguished by the name of Pelagia, because it formerly belonged to the sea. Whether these thirteen new islands were produced by the action of subterraneous fire, or by any other cause which diminished the quantity of water in the Mediterranean, it is not easy to determine. But we are informed, by Pliny himself, that the island of Hiera, in the neighbourhood of Therasia, is composed of ferruginous masses, and of earth which had been thrown up from the bottom of the sea; and, in another place, he mentions several other islands which had been formed in the same manner. Upon this subject, however, we have facts more recent, and less involved in obscurity.

On the 23d day of May, 1707, at sun-rising, there appeared, at the distance of two or three miles from the island of Therasia or Santorini, something which had the resemblance of a floating rock. Some men, stimulated by curiosity, approached it, and discovered that it had arisen from the bottom of the sea; that it increased under their feet; that oysters, and other shells, still adhered to the rocks; and that many pumice stones lay on its surface. Two days before this rock appeared, there had been a slight earthquake in Santorini. This island continued to augment considerably, without any accident, till the 14th of June. It was then about half a mile in circumference, and twenty or thirty feet high, and the earth was white and mixed with clay. After this time, the sea began to be more and

more agitated; vapours arose from it, which infested the island of Santorini, and, on the 16th of July, seventeen or eighteen rocks rose all at once from the bottom of the sea, and united into one mass. These phænomena were attended with a frightful noise, which continued two months; and flames issued from the new island, which still augmented, both in circumference and height; and the explosions were so violent, that they drove large stones to more than seven miles distance. The island of Santorini itself was regarded by the ancients as a recent production: and, in 726, 1427, and 1573, it received considerable additions, beside the small islands formed in its neighbourhood *. The same volcano, which, in the days of Seneca, raised the island of Santorini, produced, in Pliny's time, that of Hiera or Volcanella, and, in our days, the rock above described.

On the 10th of October, 1720, a great fire was seen to arise from the sea near the island of Tercera. Navigators being sent, by order of government, to examine it, they perceived, on the 19th of the same month, an island covered with fire and smoke; and a prodigious quantity of ashes was thrown to a great distance, as from a volcano, and accompanied with a noise similar to that of thunder. The earth was also perceived to shake in the neighbourhood; and a vast number of pumice stones were found floating on the

* See l'Hist. de l'Acad. des Sciences, 1708, p. 23.

sea all round the new island: this last phænomenon has sometimes been remarked in the open sea *.

The historian of the French Academy †, in relating this event, remarks, that, after an earthquake in the island of St. Michael, one of the Azores, there appeared a torrent of fire between this island and that of Tercera, which gave rise to two new rocks: and, in the subsequent year, the same historian gives the following detail:

" M. de l'Isle has informed the Academy of several particulars concerning the new island among the Azores, which he received in a letter from M. de Montagnac, consul at Lisbon. On the 18th of September, 1721, M. de Montagnac's vessel was moored off the fortress of St. Michael; and he learned the following particulars from the pilot of the port:

" During the night of the 7th or 8th of December, 1720, there was a great earthquake in Tercera and St. Michael, which islands are distant from each other about twenty-eight leagues, and a new island rose from the sea. It was, at the same time, remarked, that the point of the island of Peak, at the distance of thirty leagues, which formerly threw out flames, was extinguished. But a continual thick smoke issued from the new island, which was distinctly perceived by M. de Montagnac, as long as he

* See Phil. Trans. abridg. vol. vi. part ii. p. 154.
† Ann. 1721, p. 26.

continued in that part. The pilot assured him, that he had sailed round the island, and approached it as near as he could with safety. He sounded on the south side of it with a rope of sixty fathoms, but found no bottom. On the west side, the water was much changed: it appeared to be mixed with white, blue, and green; and, at the distance of two miles, it seemed to be shallow and boiling. On the north-west, the side from which the smoke issued, he found, at fifteen fathoms, a bottom of coarse sand. He threw a stone into the sea, and, at the place where it fell, he observed the water boil, and mount into the air with great impetuosity. The bottom was so hot, that, at two different times, it melted a piece of suet which had been fastened to the end of the plumb-line. The pilot likewise remarked, that smoke issued from a small lake, in the midst of a sandy plain. This island is nearly round, and high enough to be perceived, in clear weather, at the distance of seven or eight leagues.

"We have since learned, by a letter from M. Adrien, French consul at St. Michael, dated in March, 1722, that the new island is considerably diminished: that it is nearly on a level with the water; and that it will probably soon disappear."

From these, and many other facts of a similar nature, it is apparent that inflammable bodies exist under the bottom of the sea, and that they sometimes produce violent explosions. The

places where they happen may be considered as submarine volcanos, which differ from common volcanos only in the shorter duration of their effects; for, after the fire opens a passage to itself, the water rushes in, and extinguishes them. The elevation of new islands necessarily leaves caverns, which are soon filled by the waters; and the new ground, which consists of matter thrown out by the submarine volcano, must, in every respect, resemble that of the Monti di Cinere, and other eminences which have been raised by terrestrial volcanos. It is on account of the waters rushing into the voids and fissures produced by explosions, that submarine volcanos exhibit their effects less frequently than common volcanos, though both derive their origin from the same cause.

To subterraneous, or rather submarine fires, must be ascribed all those ebullitions of the sea, and water spouts, which have been remarked in different places by mariners: they also produce storms and earthquakes, the effects of which are felt equally at sea as upon land. The islands raised by submarine volcanos are generally composed of pumice stones and calcined rocks.

Fire has frequently been observed to issue out of the waters of the sea. Pliny tells us, that the whole surface of the Thrasymen Lake has appeared to be inflamed; and Agricola informs us, that, when a stone was thrown into the lake of Denstat in Thuringia, its descent was marked by a train of fire.

Lastly, The great quantities of pumice stones

discovered by voyagers in different parts of the ocean, as well as in the Mediterranean, evince the existence of volcanos in the bottom of the sea, which differ not from those upon land, either in the violence of their explosions, or in the matter they throw out, but only in their rarity, and in the shortness of their duration. Hence it may be remarked, that the bottom of the sea every way resembles the surface of the earth, not admitting even the exception of volcanos.

Between sea and land volcanos there are many relations. Both of them exist on the tops of mountains. The Azore islands, and those of the Archipelago, are only the points of mountains, some of which are above, and others under, the surface of the water. From the account of the new islands among the Azores, it appears that the place where the smoke issued was only fifteen fathoms deep, which, when compared with the ordinary depth of the ocean, demonstrates this place to be the top of a pretty high mountain. The same remark may be made with regard to the new island near Santorini. Its depth must have been inconsiderable, since oysters were found attached to the rocks which rose above the surface of the water. It likewise appears, that sea volcanos, as well as those upon land, have subterraneous communications; for, at the very time that the new island among the Azores arose, the summit of the volcano of St. George, in the island of Peak, sunk. It also merits observation, that new

islands never appear but in the neighbourhood of old ones; and that there are no examples of new islands in open seas: they ought, therefore, to be regarded as continuations of the ancient islands; and, when volcanos happen to exist in the latter, it is not surprising that the former should contain the same materials, which may be kindled either by fermentation alone, or by the action of subterraneous winds.

Besides, new islands produced by earthquakes, or by subterraneous fires, are few in number. But the number of those formed by slime, sand, and earth, transported by rivers, or by the motions of the sea, is almost infinite. At the mouths of rivers, such quantities of earth and sand are amassed, as frequently give rise to islands of considerable extent. The sea, by retiring from certain coasts, leaves uncovered the highest parts of the bottom, and these parts constitute so many new islands. In the same manner, when the sea encroaches upon the land, it covers the plains, and the more elevated grounds appear in the form of islands. It is for this reason that there are few islands in the open seas, and that they are so numerous near the coasts.

Fire and water, though of very opposite natures, exhibit many effects so similar, that the one may often be mistaken for the other. Beside the productions peculiar to these elements, as crystal, glass, &c., they give rise to many great phænomena, which have such strong resemblances, that they can hardly be distinguished. Water, as we have seen, elevates mountains,

and forms the greatest number of islands: some mountains and islands likewise derive their origin from fire. The same observation is applicable to caverns, fissures, gulfs, &c. Some of them are the effects of fire, and others of water.

Caverns are, in a great measure, peculiar to mountains: they are seldom or never found in plains. They are frequent in the Archipelago, and other islands; because islands are generally nothing but the tops of mountains. Caverns, like precipices, are formed by the sinking or mouldering of rocks, or, like abysses, by the action of fire; for, to make a cavern form a precipice or an abyss, nothing farther is necessary than that the tops of the opposite rocks should come together and form an arch, which must frequently happen when they are loosened at the root, and shaken by earthquakes, or by the operation of time and of the weather. Caverns may be produced by the same causes which give rise to gulfs, apertures, or sinkings of the earth; and these causes are explosions of volcanos, the action of subterraneous vapours, and earthquakes, which create such commotions in the earth, as must necessarily produce caverns, fissures, and hollows of every kind.

The cavern of St. Patrick in Ireland is not so considerable as it is famous: the same remark may be made with regard to the Grotto del Cane in Italy, and to that of Mount Beniguazeval, in the kingdom of Fez, which throws out fire. There is a very large cavern in the county of Derby in England. It is much larger

than the celebrated cavern of Bauman, near the Black Forest of Brunswick. I was informed by the earl of Morton, a philosopher more respectable for his merit than his high rank, that the entrance to this cavern, called the Devil's Hole, is larger than the door of any church; that a small river runs through it; that, after advancing some way, the vault of the cavern sinks down so low, that, in order to proceed farther, it is necessary to lie flat in a boat, and to be pushed through this narrow passage by people accustomed to the business; and that, after getting through, the roof, or arch of the cavern, rises to a great height; and, after walking a considerable way on the side of the river, the arch sinks again so low as to touch the surface of the water. Here the cavern terminates. The river, which seems to have its source in this part of the cavern, swells occasionally, and transports heaps of sand, which, by accumulating, forms a kind of blind alley, whose direction is different from that of the principal cavern.

In Carniola, near Potpechio, there is a large cavern, in which is a pretty considerable lake. Near Adelsperg, we meet with a cavern in which a man may travel two German miles. It contains several tremendous and deep precipices*. The Mendip hills in Somersetshire likewise present us with extensive caverns, and very fine grottos. Near these caverns we find veins of lead, and sometimes large oak trees, buried fifteen fathoms

* See Acta erud. Lips. anno 1689. p. 551.

deep. In the county of Gloucester, there is a large cavern called Pen-park-hole, at the bottom of which we meet with thirty-two fathoms of water. Here are also veins of lead.

It is apparent that the Devil's Hole, and other caverns, from which large springs or brooks issue, have been gradually formed by the operation of the water, and their origin cannot be ascribed to earthquakes or volcanos.

One of the largest and most singular caverns we are acquainted with, is that of Antiparos, of which M. Tournefort has given a complete description. We first find a rustic cave about thirty feet wide, divided by some natural pillars. Between two pillars on the right, the ground slopes gently, and then more precipitately for about twenty paces to the bottom of the cavern. This is the passage to the grotto or interior cave, and is nothing but a dark hole, through which a man cannot pass without stooping and the assistance of lights. We then descend, by means of a rope fixed at the entrance, a horrible precipice, and arrive on the borders of another still more tremendous, with corresponding abysses on the left. By a ladder placed on the margin of these gulfs, we get over a vast perpendicular rock. We then continue to slip through places less dangerous. But, when we think ourselves in the greatest safety, we are suddenly stopped by a frightful pass; to escape through which, we are obliged to glide on our backs along a large rock, and to descend by means of a ladder. When we arrive at the bottom of the ladder, we

stumble for some time among irregular rocks, and then the famous grotto presents itself. This grotto is about 300 fathoms below the surface of the earth, and it appears to be about forty fathoms high, and fifty wide. It is full of large and beautiful stalactites, which both depend from the roof of the vault and cover the floor*.

In that part of Greece called Achaia by the ancients, now Livadia, there is a large cavern in a mountain which was formerly famous for the oracles of Trophonius: it is situated between the lake of Livadia and the sea, from which, at the nearest part, it is distant about four miles; and there are no less than forty subterraneous passages, through which the waters run under the mountain†.

In all countries which are subject to earthquakes or volcanos, caverns are frequent. The structure of most of the islands of the Archipelago is exceedingly cavernous. The islands in the Indian Ocean, and particularly the Moluccas, appear to be chiefly supported upon vaults. The land of the Azores, of the Canaries, of the Cape de Verd islands, and, in general, of almost all small islands, is, in many places, hollow, and full of caverns; because these islands, as formerly remarked, are only the tops of mountains, which have suffered great convulsions either from volcanos, or by the action of the waters, of frosts,

* See Tournefort's Voyage to the Levant.

† See Gordon's Geography, p. 179.

and of other injuries of the weather. In the Cordeliers, where volcanos and earthquakes are frequent, there are many caverns, precipices, and abysses.

The famous labyrinth in the island of Crete, is not the work of nature alone. We are assured by M. Tournefort, that, in many parts of it, the operation of men is evident; and, it is probable, that this is not the only cavern which has been augmented by art. Mines and quarries are constantly digging; and after these have been long deserted, it is not easy to determine whether such excavations have been the effects of nature or of art. Some quarries are amazingly extensive. That of Maestricht, for instance, is sufficient to shelter 50,000 men, and is supported by more than 1,000 pillars of twenty feet high; and the earth and rock above is twenty-five fathoms thick*. The salt mines of Poland exhibit excavations still more extensive. Near large cities, quarries and artificial hollows are common. But we must proceed no farther in detail. Besides, the operations of men, however great, will always make but an inconsiderable figure in the history of nature.

In my Theory of the Earth, I mentioned only two kinds of caverns, the one produced by the fire of volcanos, and the other by the motion of subterraneous waters. Those two species of caverns are not situated at great depths.

* See Phil. Trans. abridg. vol. ii. p. 463.

They are even new, when compared with those vast cavities, which were formed at the time the globe first assumed a solid form; for, at this period, all the superficial eminences and hollows, and all the cavities in the interior parts of the earth, especially near the surface, were produced. Several of those caverns, produced by the primitive fire, after being supported for some time, have afterwards split by cooling, which diminishes the volume of every kind of matter; these would soon fall in, and, by their sinking, form basins or reservoirs for the sea, into which the waters, formerly much elevated above this level, ran, and abandoned the lands which they originally covered. It is more than probable, that a certain number of these ancient caverns still subsist in the interior parts of the globe, and, by their sinking, may produce similar effects, and give rise to new receptacles to the waters. In this case, they will partly abandon the basin which they now occupy, and run, by their natural propensity, into these lower places. For example, we find beds of sea shells in the Pyrennees 1,500 fathoms above the present level of the ocean. Hence it is certain, that the waters, when these shells were formed, rose 1,500 fathoms higher than they do at present. But, when the caverns, which supported the lands that are now the bed of the Atlantic Ocean, sunk, the waters which covered the Pyrennees, and the whole of Europe, would run with rapidity into these reservoirs, and, of course, leave uncovered all the lands in this part of the world.

The same revolution would extend to every other country. The water appears to have never reached the summits of the highest mountains, because they exhibit no relics of marine productions, and no sufficient marks of a long abode of the waters. However, as some of the matters of which they are composed, though all of the vitrescent kind, seem to have derived their solidity and consistence from the intervention and cement of water, and as they appear to have been formed, as already remarked, in the masses of sand, or glass dust, which formerly lay on the peaks of mountains, but which, in the progress of time, have been carried down to their bottoms by the rains, we cannot pronounce positively, that the waters of the sea never stood higher than the places where shells are now found: the waters have perhaps stood much higher, even before their temperature permitted the existence of shells. The greatest height reached by the universal ocean is to us unknown. But we know that the waters were elevated from 1,500 or 2,000 fathoms above their present level; since shells are found in the Pyrennees at 1,500 fathoms, and in the Cordeliers at 2,000.

If all the peaks of mountains were formed of solid glass, or of other matters immediately produced by fire, it would be unnecessary to have recourse to the abode of the waters, or to any other cause, in order to conceive how they assume their consistence. But most peaks of mountains seem to be composed of matters,

which, though vitrifiable, have acquired their solidity by the intervention of water. We cannot, therefore, determine whether their consistence is solely owing to the primitive fire, or whether the intervention and cement of water were not requisite to complete the operation of fire, and to bestow on these vitrifiable masses the qualities which they possess. Besides, this supposition prevents not the primitive fire, which at first produced the greatest inequalities on the globe, from being the chief cause of those chains of mountains that traverse its surface, and particularly of their cores or nuclei; but the contours of these same mountains have perhaps been disposed and fashioned by the waters at a subsequent period; for it is upon these contours, and at certain heights, that shells and other productions of the sea are found.

To acquire a clear notion of the ancient caverns formed by the primitive fire, we must suppose the globe to be deprived of all its waters, and of all the matters which cover its surface, to the depth of 1,000 or 1,200 feet. By removing in idea this external bed of earth and water, the globe will present to us the form it possessed about the time of its first consolidation. The whole mass was composed of vitreous rock, or, if you will, of melted glass; and this matter, in cooling and acquiring consistence, produced, like all other melted bodies, eminences, depressions, and cavities, upon the whole surface of the globe. These internal cavities, formed by

fire, are the primitive caverns, and they are more numerous in the southern than in the northern regions; because the rotatory motion, which elevated the equatorial regions before consolidation, likewise produced the greatest derangement of the matter, and, by retarding the consolidation, would concur with the action of the fire in giving rise to a greater number of inequalities in this than in any other part of the globe. The waters coming from the poles could not approach those burning regions before they cooled. The vaults which supported these regions have successively fallen in, the surface sunk and broke in a thousand places. For this reason, the greatest inequalities of the globe are found in the equatorial regions. There the primitive caverns are more numerous than in any other part of the earth. They are likewise more profound, *i. e.*, perhaps five or six leagues deep; because the matter of the globe, while in a liquid state, was agitated to that depth by the motion of rotation. But all the caverns in high mountains derive not their origin from the operation of primitive fire. Those alone which are deeply situated below the mountains can be ascribed to this cause. The more exterior and more elevated have been formed, as already remarked, by the operation of secondary causes. Hence the globe, deprived of its waters and the matters transported by them, would present to us a surface much more irregular than it appears with the aid of this covering. The great chains of moun-

tains, and their peaks and ridges, have not now the appearance of half of their real height. The whole are attached by their bases to a vitrifiable rock, and are of the same nature. Thus we should reckon three species of caverns produced by nature: the first by the force of the primitive fire; the second by the action of water; and the third by that of subterraneous fires: each of these caverns, though different in their origin, may be distinguished by examining the matters they contain, or by which they are surrounded.

Volcanos and water, which form caverns in the bowels of the earth, produce likewise on its surface fissures, precipices, and abysses. At Cajeta in Italy, there is a mountain which had been formerly split by an earthquake in such a manner, that the separation seems to have been made by the hands of men. We have already mentioned the Wheel-track, or great fissure in the island of Machian, the abyss of Mount Ararat, the port or gap in the Cordeliers, that of Thermopylæ, &c. To these we might add the gap in the mountain of the Troglodites in Arabia, and that of the Ladders in Savoy, which was begun by nature, and finished by Victor-Amadæus. Considerable sinkings in the earth, the fall of rocks, and the subversion of mountains, are frequently produced by the waters, as well as by subterraneous fires. Of this many examples might be given.

" In the month of June, 1714, a part of the mountain of Diableret in Valois fell suddenly,

and, in a few hours, the sky being serene, it appeared to have assumed a conical figure. It destroyed fifty-five houses, besides several men, and a great many cattle; and it covered a league square with its ruins. The sky was darkened with the dust: the collection of stones and earth, which were amassed on the plain, exceeded thirty Rhenish perches in height, dammed up the waters, and gave rise to new lakes of considerable depths. But this phaenomenon was not accompanied with the least vestige of bitumen, sulphur, or calcined lime-stone; nor, consequently, of subterraneous fire: the base of this great rock appeared to be rotten, and reduced to powder*."

There is a remarkable example of these sinkings near Folkstone in the county of Kent. The hills in the neighbourhood sunk insensibly, without any earthquake or other commotion. The interior parts of these hills consist of rocks and chalk; and, by their sinking, they have pushed part of the adjacent land into the sea. A well attested relation of this fact may be seen in the Philosophical Transactions †.

In 1618, the town of Pleurs was buried under the rocks at the foot of which it had been situated. In 1678, a great inundation was occasioned, in Gascony, by the sinking of some portions of one of the Pyrennees, which forced out the water that had been pent up in the subterraneous caverns of these mountains. In the

* Hist. de l'Acad. des Sciences, ann. 1715, p. 4.

† Abridg. vol. iv. p. 250.

year 1680, a still greater inundation was produced in Ireland, by the sinking of a mountain into caverns which had been full of water. It is not difficult to investigate the cause of these effects. It is well known, that subterraneous waters are every where frequent. These waters gradually work away sand and earth in their passages; and, consequently, they may, in the course of time, destroy the stratum of earth which serves as a basis to the mountain: if this stratum fail more on one side than on another, the mountain must, of necessity, be overturned; or, if the base wastes gradually and equally throughout, the mountain will sink, without being overturned.

Having mentioned a few of those convulsions and changes produced in the earth by what may be called the accidents of nature, we must not pass over in silence the perpendicular fissures in the different strata. These fissures are obvious, not only in all rocks and quarries, but in clays, and in every species of earth which has never been removed from its natural position. They are called perpendicular fissures; because, like the horizontal strata, they are never oblique, but from some accidental change. Woodward and Ray talk of fissures, but in a general and confused manner, and they never mention them under the appellation of perpendicular fissures, because they imagined that they might be indifferently either oblique or perpendicular. No author has hitherto attempted to explain their origin, though it is apparent, as remarked in a former article,

that they have been occasioned by the drying of the materials which compose the horizontal strata. In whatever manner this drying should happen, perpendicular fissures must have been a necessary consequence; for the matter of the horizontal strata could not be diminished in size, without splitting, at different distances, in a direction perpendicular to the strata themselves. Under perpendicular fissures, I comprehend, not only the natural cracks in rocks, but all those separations which have been effected by convulsive accidents. When a mass of rock has suffered any considerable motion, the fissures are sometimes placed obliquely; but it is because the mass itself is oblique; and the smallest attention to quarries of marble and lime-stone, or to great chains of rocks, will convince us, that the general direction of fissures is perpendicular to the strata in which they are found.

The bowels of mountains are chiefly composed of parallel strata of stones and rocks. Between the parallel strata, we often meet with beds of matter softer than stone; and the perpendicular fissures are filled with sand, crystals, metals, &c. The formation of these last bodies is more recent than that of the horizontal strata in which sea shells are found. The rains have gradually detached the sand and earth from the tops of mountains, and left the stones and rocks bare, which afford an opportunity of distinguishing with ease both the parallel strata and the perpendicular fissures. On the other hand, the rains and rivers have successively covered the

plains with considerable quantities of earth, sand, gravel, and other bodies which are either soluble in, or easily divisible by water. Of these have been formed beds of tufa, of soft stone, of sand, of rounded gravel, and of earth mixed with vegetable substances. But these beds contain no sea shells, or, at most, but fragments of them; which have been detached from the mountains along with the earth and gravel. These recent beds should be carefully distinguished from the ancient and original strata, in which we almost universally find a great number of entire shells placed in their natural situation.

In examining the internal order and distribution of the materials of a mountain, composed of common stone or calcinable lapidific matter, we generally find, after removing the vegetable soil, a bed of gravel, of the same nature and colour with the stones which predominate in the mountain; and, under the gravel, we meet with the solid rock. When the mountain is cut by a deep trench or ravine, the different banks or strata are easily distinguishable. Each horizontal stratum is separated by a kind of joint or suture, which is likewise horizontal. These strata generally augment in thickness, in proportion to their depth or distance from the top of the mountain; and they are all divided, vertically, by perpendicular fissures. In general, the first stratum under the gravel, and even the second, are not only thinner than those which form the base of the mountain, but so much cut by per-

pendicular fissures, that small portions of them only have any coherence. Most of these fissures, which exactly resemble the cracks in earth that has been dried, gradually disappear as they descend, and, at the base of the mountain, where they cut the larger strata in a more regular and more perpendicular manner than those near the surface, their number is much smaller.

These strata of rock often extend, without interruption, to great distances. Stones of the same species likewise are almost uniformly found in opposite mountains, whether they be separated by a narrow neck or a valley; and the strata never entirely disappear, unless when the mountain terminates in a large and level plain. Sometimes we find, between the vegetable soil and the gravel, a stratum of marl, which communicates its colour, and other qualities, to the neighbouring beds: the perpendicular fissures in the inferior rocks are, in this case, filled with marl, where it acquires a hardness equal, in appearance, to that of the surrounding stone; but, when exposed to the air, it splits, and becomes soft and ductile.

The beds of stone which compose the tops of mountains are generally soft and tender, but those near the base are exceedingly hard. The first is commonly white, and of a grain so fine as to be hardly perceptible. In proportion as they descend, the rocks become more compact, and have a better grain; and the lowest beds are not only harder than the superior ones, but are also

more compact and heavy. Their grain is fine and brilliant; and they are often so brittle as to break as purely and neatly as flint.

The heart of a mountain, then, is composed of different strata of stones, which are harder or softer in proportion to their distance from the summit; and they are broad at the base, and sharp and narrow at the top. The last is, indeed, a necessary result of the first: for, as the stones grow harder as they descend, it is natural to think, that the currents, and other motions of the water, which scooped out the valleys, and formed the contours of the mountains, must have gradually consumed, by their lateral friction, the materials of which the mountains are composed; and that this consumption would be proportioned to the hardness or softness of the matter acted upon. But, as the upper strata are known to be softest, and as their density increases according as they approach the base, the mountains must, of necessity, have assumed their present inclined, and somewhat conical figure. This is one great cause of the declivity of mountains; and it must always become more gentle, in proportion as the earth and gravel are brought down by the rain from their summits. For these reasons, the declivity of hills and mountains, composed of calcinable bodies, is less than that of those which consist of granite, or of flint in large masses. The latter generally rise almost perpendicularly to very great heights; because in these masses of vitrifiable matter, the superior, as well as the inferior strata,

are extremely hard, and have presented nearly an equal resistance to the operation of the waters.

Though, in the tops of some hills which are flat, and pretty extensive, we find hard stone immediately under the vegetable soil; yet it should be remarked, that, in every example of this kind, what appears to be the summit of a hill is only a continuation of some more elevated hill in the neighbourhood, the upper strata of which consist of soft, and the inferior strata of hard stone; and the hard stone found on the top of the first hill is only a continuation of the under strata of the higher hill.

Still, however, on the tops of hills which are not surmounted by higher grounds, the stone is mostly of a soft and friable nature; and hard stone cannot be had without digging to a considerable depth. It is between these layers of hard stone only that marble is to be found; and it is variegated with different colours by metallic substances carried down by rain-water, and filtrated through the strata: and it is probable that, in every country which furnishes stones, marble would be found, if pits were dug to a sufficient depth: "Quoto enim," says Pliny, "loco non suum marmor invenitur?" It is, in fact, a more common stone than is generally imagined, and differs from other stones only in the fineness of its grain, which renders it compact, and susceptible of a fine and brilliant polish.

Both the perpendicular fissures, and the horizontal joints of quarries, are often filled, or encrusted, with concretions, which are sometimes

transparent, and of regular figures, as crystals, and sometimes earthy and opaque. Water runs through the perpendicular fissures, and even penetrates the close texture of the stone itself. Stones which are porous imbibe water so copiously, that frost splits them in pieces. The rain-waters, by filtrating through different strata, are impregnated with a great variety of substances. They first sink through the perpendicular fissures; they then penetrate the strata of stone, and deposit, in the horizontal joints, as well as in the perpendicular fissures, such matter as they collect in their course, and give rise to different concretions, according to the nature of these substances. For example, when the water filtrates through marl, clay, or soft stone, the matter which it deposits is nothing but a fine, pure marl, and commonly appears in the perpendicular fissures under the form of a porous, soft, white, light substance, known among naturalists under the name of *Lac Lunæ*, or *Medulla Saxi.*

When veins of water, charged with stony matter, run along the horizontal joints of soft stone or chalk, this matter adheres to the surface of the stones, and forms a white, scaly, light, and spongy crust, which, from its resemblance to the agaric, has been called *mineral agaric*. But if the strata through which the water penetrates be hard stone, the filter being closer, the water it allows to pass will be impregnated with a stony matter more pure and homogeneous; and, consequently, the particles, being capable of a

more compact and intimate union, will form concretions, nearly of equal density with the stone itself, and somewhat transparent. In quarries of this kind, the stones are encrusted with undulated concretions, which entirely fill up the horizontal joints.

In grottos and cavities of rocks, which may be regarded as the basins or common sewers of the perpendicular fissures, the different directions of the veins of water give different forms to the concretions that result from them. These forms are generally wreathed, or resemble an inverted cone, attached to the roof of the cavern; or, rather, they are white, hollow cylinders, composed of concentric coats. The impregnated waters sometimes fall in drops upon the floor of the cavern, and form columns, and a thousand whimsical figures, to which naturalists have given the different appellations of *stalactites, stalagmites, osteocollæ,* &c.

Lastly, When the concreting juices issue immediately from marble, or very hard stone, the lapidific matter is rather dissolved than suspended in the water, and it forms a kind of columns with triangular points, which are transparent, and consist of oblique coats. This substance is distinguished by the name of *spar* or *spalt.* It is transparent and colourless, except when the stone or marble through which it filtrates contains metallic particles. This spar is of equal hardness with the stone itself, and it dissolves in acids, and calcines with the same degree of heat. Hence it is evident, that spar is a true stone, and

perfectly homogeneous. It may even be considered as a pure and elementary stone.

Most naturalists, however, consider this as a distinct substance, existing independent of stone: it is the lapidific or crystalline juice, which, in their estimation, not only cements the particles of common stone, but even those of flint. This juice, they allege, daily augments the density of stones by reiterated filtrations, and at last converts them into flint: when concreted into spar, it perpetually receives fresh supplies of still purer juice, which increases both its hardness and its density, till it changes to the consistence of glass, then to that of crystal, and at last it is converted into genuine diamond.

But, on this supposition, Why does the lapidific juice produce stone in some provinces only, and nothing but flint in others? It may be said, that the one province is less ancient than the other, and that the juice has not had time sufficient to complete its natural operations. But in this there is not the shadow of probability. Besides, from whence does this juice proceed? If it gives rise to stones and flints, from whence does it derive its own origin? It is obvious, that it has no existence independent of those substances which alone can impart to the water that penetrates them a petrifying quality, that uniformly corresponds with their nature and peculiar properties. Thus when it filtrates through stone, it produces spar; when it issues from flint, it forms crystal; and there are as many species of this

juice as of bodies from which it proceeds. Experience confirms this account of the matter. The waters which filtrate through quarries of common stone form tender and calcinable concretions similar to the stones themselves. On the other hand, the waters which exude from granite or from flint, produce concretions hard and vitrifiable, and they have all the other properties of flint, as the former had all those of stone. In the same manner, the waters, which filtrate through mineral and metallic substances, give rise to pyrites, marcasites, and metallic grains.

It was formerly remarked, that all matter might be divided into the two great classes of vitrifiable and calcinable. Clay and flint, marl and stone, may be regarded as the two extremes of each class, the intervals between which are filled with an almost infinite variety of mixts, that have always one or other of these substances for their basis.

The substances belonging to the first class can never acquire the properties of those of the latter. Stone, however ancient, will for ever be equally removed from the nature of flint, as clay is from that of marl. No known agent can ever force them from the circle of combinations peculiar to their nature. Places which produce marble and stone will always continue to do so, as infallibly as those that produce only sandstone, flint, and granite, will never produce lime-stones or marble.

If we examine the order and distribution of the materials of a hill composed of vitrifiable substances, we shall generally find, under the vegetable soil, a stratum of clay, which is likewise a vitrifiable substance, analogous to flint, and which, as already remarked, is only a decomposition of vitrifiable sand; or, rather, we shall find, under the soil, a stratum of vitrifiable sand. This stratum of clay or of sand corresponds with the bed of gravel in hills consisting of calcinable matters. Below the stratum of clay or of sand, we meet with some beds of free-stone, which seldom exceed half a foot in thickness, and they are divided into small portions by perpendicular fissures. Under these are several strata of the same matter, and likewise beds of vitrifiable sand. In proportion as we descend, the free-stone is more dense, and its thickness increases. Below these, we find what I call live rock, or flint in large masses, a substance so hard as to resist the file, and all kinds of acids, more powerfully than vitrifiable sand or powder of glass, upon which aquafortis seems to have some effect. When struck with another hard body, it throws out sparks of fire, and exhales a penetrating sulphureous vapour. This flinty substance is commonly found along with beds of clay, of slate, of pit-coal, of vitrifiable sand; and it corresponds to the strata of hard stone and marble, which serve as the bases of hills that consist of calcinable matter.

The waters, in passing through the perpendicular fissures, and in penetrating the strata of

vitrifiable sand, of free-stone, of clay, and of slate, are impregnated with the finest and most homogeneous particles of these substances, and produce various concretions, such as talc, asbestos, and other bodies, which owe their existence to distillation through vitrifiable matter.

Flint, notwithstanding its hardness and density, has, like marble and common stone, its exudations, from which result stalactites of different species, varying in transparency, colour, and configuration, according to the nature of the flint that produces them, and to the different metallic or heterogeneous particles it contains. Rock crystal, all the precious stones, and even the diamond itself, may be regarded as stalactites of this kind. The flints in small masses, the strata or coats of which are generally concentric, are only stalactites or parasitical stones from the flints in large masses; and most of the fine opaque stones are nothing but species of flint. The substances produced by the vitrifiable class of bodies are not, as we have seen, so various as the concretions formed by those of the calcinable. Most of the concretions formed by flint are hard and precious stones; but those produced by calcarious stones are friable, and of no value.

Perpendicular fissures are found in flint rocks as well as in stone. They are even frequently larger in flint, which proves this substance to be drier than stone. Both the hill consisting of calcinable, and that composed of vitrifiable matter, have clay or vitrifiable sand for their bases, which

are the most commonly diffused matters of the globe, and which I regard as the lighcest, being the scoriæ of the vitrified matter that constitutes the interior parts of the earth. Thus all mountains, as well as plains, are founded either on clay or sand. We have seen, for example, in the pits of Amsterdam, and in that of Marly-la-Ville, that vitrifiable sand was always the deepest stratum.

It may be observed, in most bare rocks, that the walls of perpendicular fissures, whether they be narrow or wide, correspond as exactly with each other as split pieces of wood. In the large quarries of Arabia, which consist mostly of granite, the perpendicular fissures are frequent; and though some of them are twenty or thirty yards wide, the sides correspond exactly, and leave a deep cavity between them *. It is likewise common to find, in perpendicular fissures, shells divided into two pieces, each piece remaining attached to the opposite sides of the fissure; which proves that these shells were deposited in the solid stratum before it was split †.

In some quarries mentioned by Mr. Shaw, the perpendicular fissures are exceedingly large; and for this reason, perhaps, they are less numerous. In quarries of granite and flint in large masses, blocks of stone may be raised, as the obelisks and columns at Rome, of 60, 80, 100, and 150 feet long, without the least interruption. It appears, that these vast blocks have been raised from the

* See Shaw's Travels. † See Woodward, p. 298.

same quarry, and, like some species of free-stone, that they may be had of any given thickness. In other substances, the perpendicular fissures are very narrow, as in clay, in marl, and in chalk; and they are wider in marble and hard stone. Some are imperceptible, because they have been filled with a matter nearly similar to that of the stone itself; but still they interrupt the continuity of the stones, and are called *hairs* by the workmen. I have often remarked, that these hairs in marble and stone differed from perpendicular fissures only in the separation of parts not being complete. These species of fissures are filled with a transparent matter, which is a true spar. In quarries of free-stone, the fissures are numerous, and considerably large, because rocks of this kind have often a less solid base than that which supports marble or limestone, the former generally resting upon a fine sand, and the latter upon clay. In many places, free-stone is not to be found in large masses; and in most quarries, where this stone is good, the blocks lie irregularly upon one another, in the form of cubes or parallelopipeds, as in the hills of Fountainbleau, which appear, at a distance, like the ruins of old buildings. This irregular disposition has been occasioned by the sandy foundation of these hills allowing the blocks to sink and tumble upon each other, especially where quarries have been formerly wrought, which has given rise to a great variety of fissures and intervals between the different blocks: and it may be remarked, in all countries abounding

with sand and free-stone, that there are many fragments of rocks and large stones in the middle of the plains and valleys; and that, on the contrary, in countries abounding with marble and hard stone, these scattered fragments, which have rolled down from the hills, are exceedingly rare. This phænomenon is owing to the different solidities of the bases upon which these stones are supported, and to the extent of the banks of marble or lime-stone, which is always more considerable than that of free-stone.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE XVIII.

Of the Effects of Rains—Of Marshes, Subterraneous Wood and Waters.

IT has already been remarked, that rains, and the currents of water which they produce, continually detach, from the summits and sides of mountains, earth, gravel, &c., and carry them down to the plains; and that the rivers transport part of them to the sea. The plains, therefore, by fresh accumulations of matter, are perpetually rising higher; and the mountains, for the same reason, are constantly diminishing both in size and elevation. Of the sinking of mountains, Joseph Blancanus relates several facts which were publicly known in his time. The steeple of the village of Craich, in the county of Derby, was not visible in 1572, from a certain

mountain, on account of a higher mountain which intervened; but eighty or one hundred years afterwards, not only the steeple, but likewise part of the church, were visible from the same station. Dr. Plot gives a similar example of a mountain between Sibbertoft and Ashby, in the county of Northampton. Sand, earth, gravel, and small stones, are not only carried down by the rains, but they sometimes undermine and drive before them large rocks, which considerably diminish the height of mountains. In general, the rocks are pointed and perpendicular in proportion to the height and steepness of mountains. The rocks in high mountains are very straight and naked. The large fragments which appear in the valleys have been detached by the operation of water and of frosts. Thus sand and earth are not the only substances detached from mountains by the rains; they attack the hardest rocks, and carry down large fragments of them into the plains. At Nant-phrancon, in 1685, a part of a large rock, which was supported on a narrow base, being undermined by the waters, fell, and split into a number of fragments, the largest of which made deep trenches in the plain, crossed a small river, and stopped on the other side. To similar accidents we must ascribe the origin of all those large stones which are found in valleys adjacent to mountains. This phænomenon, as formerly remarked, is more common in countries where the mountains are composed of sand and free-stone, than

in those the mountains of which consist of clay and marble; because sand is a less solid basis than clay.

To give an idea of the quantity of earth detached from mountains by the rains, we shall quote a passage on this subject from Dr. Plot's Natural History of Stafford. He remarks, that a great number of coins, struck in the reign of Edward IV. *i. e.* 200 years ago, were found buried eighteen feet below the surface: hence, he concludes, that the earth, which is marshy where the coins were found, augments about a foot in eleven years, or an inch and a twelfth each year. A similar observation may be made on trees buried seventeen feet below the surface, under which were found medals of Julius Cæsar. Thus, the soil of the plains is considerably augmented and elevated by the matters washed down from the mountains.

The rupture of caverns, and the action of subterraneous fires, are the chief causes of the great revolutions which happen in the earth; but they are often produced by smaller causes. The filtration of the water, by diluting the clay, upon which almost all calcarious mountains rest, has frequently made those mountains incline and tumble down. Of these remarkable events I shall subjoin some examples.

"In the year 1757," says M. Perronet, "a part of the ground situated about half way before we arrive at the Castle of Croix-fontaine, opened in many places, and successively tumbled down.

The terrace wall, which inclosed this ground, was overturned, and the road, which was formerly at the foot of the wall, was obliged to be carried to a considerable distance. . . . . . This ground rested upon a base of inclined earth." This learned and chief engineer of our highways and bridges mentions another accident of the same kind, which happened, in the year 1733, at Pardines, near Issoire, in Auvergne. The ground, for about 400 fathoms in length by 300 in breadth, descended upon a pretty distant meadow, with all its houses, trees, and herbage. He adds, that considerable portions of ground are sometimes transported either by the rupture of reservoirs of water, or by the sudden melting of snows. In 1757, at the village of Guet, about ten leagues from Grenoble, on the road to Briançon, the whole ground, which lies on a declivity, slipped, and descended in an instant towards Drac, which is about a mile distant. The earth split in the village, and the part which moved off was six, eight, and nine feet lower than its former station. This ground was situated on a pretty solid rock, which was inclined to the horizon about forty degrees *.

To these examples I shall add another fact, of which I have been a constant witness, and which has cost me a considerable expense. The detached rising ground, upon which the town and old castle of Montbard are situated, is elevated 140 feet above the level of the river, and its most

* Hist. de l'Acad. des Sciences, ann. 1769, p. 233.

rapid descent is to the north-east. This rising ground is crowned with calcarious rocks, the strata of which, when taken together, are fifty-four feet thick. They every where rest upon a mass of clay, which, of course, before reaching the level of the river, is eighty-six feet thick. My garden, which is surrounded with several terraces, is situated on the top of this rising ground. From twenty-five to twenty-six fathoms of the last terrace wall on the north-east side, where the declivity is greatest, gave way all at once, carrying along the inferior ground, which would have gradually descended to the level of the ground near the river, if its progressive motion had not been prevented by taking down the whole wall. This wall was seven feet thick, and founded on clay. The movement of the earth was very slow: I perceived that it was evidently occasioned by the insinuation of water. All the water which falls upon the platform on the top of this rising ground, penetrates through the fissures of the rocks, and reaches the clay upon which they rest: of this fact we are ascertained by two wells dug from the top of the rock to the clay. All the rain-water, therefore, which falls upon this platform and the adjacent terraces, collects upon the clay where the perpendicular fissures of the rock terminate. The water gives rise to small rills in different places, which are rendered still more apparent by several wells dug below the rocks. Wherever this mass of clay is cut by ditches, we see the water filtrating from above. It is not, therefore, surprising, that walls, however solid,

should slip upon this first bed of moist clay, if they are not founded much lower, as I have done in rebuilding them. The same thing, however, has happened on the north-west side, where the declivity is gentler, and no rills of water appear. The clay had been removed at the distance of twelve or fifteen feet from a great wall, of eleven feet thick, thirty-five feet high, and twelve fathoms long. This wall is constructed of good materials, and has subsisted more than 900 years. The cut from which the clay was removed, though not above four or five feet deep, has produced a movement in this immense wall. It declines from the perpendicular about fifteen inches, and I could only prevent its downfal by abutments of seven or eight feet thick, and founded at the depth of fourteen feet.

From these facts I drew the following conclusion, which is not so interesting at present as it would have been in ages that are past, that there is not a castle or fortress, situated upon heights, which might not be easily tumbled into the plain by a simple cut of ten or twelve feet deep and some fathoms wide. This cut should be made at a small distance from the last wall, and upon that side where the declivity is greatest. This method, of which the ancients never dreamed, would have saved them the operation of battering rams and other engines of war; and, even at present, might be employed, in many cases, with advantage. I am convinced by my eyes, that, when these walls slipt, if the cut made for rebuilding them had not been

speedily filled with strong mason work, the ancient walls, and the two towers that have subsisted in good condition 900 years, and one of which is 125 feet high, would have tumbled into the valley, along with the rocks upon which they are founded. As most of our hills composed of calcarious stones rest upon a clay base, the first strata of which are always more or less moistened with the waters that filtrate through the crevices of the rocks, it appears to be certain, that, by exposing these moistened beds to the air by a cut, the whole mass of rocks and earth resting upon the clay would slip, and in a few days tumble into the cut, especially during wet weather. This mode of dismantling a fortress is more simple than any hitherto invented; and experience has convinced me that its success is certain.

The sand, gravel, and earth, carried down from the mountains into the plains, form beds which ought not to be confounded with the original strata of the globe. To the former belong the beds of tufa, of soft stone, and of sand and gravel which have been rounded by the operation of water. To these may be added those beds of stone which have been formed by a species of incrustation, none of which derive their origin from the motion or sediments of the sea. In these strata of tufa and of soft imperfect stones, we find a number of different vegetables, leaves of trees, land or river shells, and small terrestrial animals, but never sea shells, or other productions of the ocean This circumstance, joined

to their want of solidity, evidently proves, that these strata have been superinduced upon the dry surface of the earth, and that they are more recent than those of marble and other stones, which contain sea shells, and have been originally formed by the waters of the sea. Tufa, and other new stones, appear to be hard and solid when first dug out of the earth; but they soon dissolve after being exposed to the operation of the weather. Their substance is so different from that of true stone, that, when broken down in order to make sand of them, they change into a kind of dirty earth. The stalactites, and other stony concretions, which M. Tournefort apprehended to be marbles that had vegetated, are not genuine stones. We have already shown, that the formation of tufa is not ancient: and that it is not entitled to be ranked with stones. Tufa is an imperfect substance, differing from stone or earth, but deriving its origin from both by the intervention of rain-water, in the same manner as incrustations are formed by the waters of certain springs. Thus, the strata of these substances are not ancient; nor have they, like the other species, been formed by sediments from the waters of the ocean. The strata of turf are also recent, and have been produced by successive accumulations of half corrupted trees and other vegetables, which owe their preservation to a bituminous earth. No production of the sea ever appears in any of these new strata. But, on the contrary, we find in them many vegetables, the bones of land animals, and land and river shells. In the

meadows near Ashly, in the county of Northampton, for example, they find, several feet below the surface, snail shells, plants, herbs, and several species of river shells, well preserved; but not a single sea shell appears *. All these new strata have been formed by the waters on the surface changing their channels, and diffusing themselves on all sides. Part of these waters penetrate the earth, and run along the fissures of rocks and stones. The reason why water is so seldom found in high countries, or on the tops of hills, is, because high grounds are generally composed of stones and rocks. To find water, therefore, we must cut through the rocks till we arrive at clay or firm earth. But, when the thickness of the rock is great, as in high mountains, where the rocks are often 1,000 feet high, it is impossible to pierce them to their base; and consequently it is impossible to find water in such situations. There are even extensive countries that afford no water, as in Arabia Petrea, which is a desert where no rains fall, where the surface of the earth is covered with burning sands, where there is hardly the appearance of any soil, and where nothing but a few sickly plants are produced. In this miserable country, wells are so rare, that travellers enumerate only five between Cairo and Mount Sinai, and the water they contain is bitter and saltish.

When the superficial waters can find no outlets or channels, they form marshes and fens.

* See Phil. Trans. abridg. vol. iv. p. 271.

The most celebrated fens in Europe are those of Russia, at the source of the Tanais; and those of Savolaxia and Enasak, in Finland: there are also considerable marshes in Holland, Westphalia, and other countries. In Asia are the marshes of the Euphrates, of Tartary, and of the Palus Meotis. However, marshes are less frequent in Asia and Africa than in Europe. But the whole plains of America may be regarded as one continued marsh; which is a greater proof of the modernness of this country, and of the scarcity of its inhabitants, than of their want of industry.

There are extensive fens in England, particularly in Lincolnshire, near the sea, which has lost a great quantity of land on one side, and gained as much on the other. In the ancient soil, many trees are found buried under the new earth, which has been transported and deposited by the water: the same phænomenon is common in the marshes of Scotland. Near Bruges in Flanders, in digging to the depth of forty or fifty feet, a vast number of trees were found, as close to each other as they are in a forest. Their trunks, branches, and leaves, were so well preserved, that their different species could be easily distinguished. About 500 years ago, the earth where these trees were found was covered with the sea: and, before this time, we have neither record nor tradition of its existence. It must, however, have been dry land when the trees grew upon it. Thus the land, that, in some remote period, was firm, and covered with wood.

has been overwhelmed with the waters of the sea, which, in the course of time, have deposited forty or fifty feet of earth upon the ancient surface, and then retired. A number of subterraneous trees was likewise discovered at Youle in Yorkshire, near the river Humber. Some of them are so large as to be of use in building; and it is affirmed that they are as durable as oak. The country people cut them into long thin slices, and sell them in the neighbouring villages, where the inhabitants employ them for lighting their pipes. All these trees appear to be broken; and the trunks are separated from the roots, as if they had been thrown down by a hurricane or an inundation. The wood appears to be fir, it has the same smell when burnt, and makes the same kind of charcoal *. In the Isle of Man, there is a marsh called Curragh, about six miles long and three broad, where subterraneous fir trees are found; and, though eighteen or twenty feet below the surface, they stand firm on their roots †. These trees are common in the marshes and bogs of Somerset, Chester, Lancashire, and Stafford. In some places, there are subterraneous trees, which have been cut, sawed, and squared by the hands of men; and even axes, and other implements, are often found near them. Between Birmingham and Bromley, in the county of Lincoln, there are hills of a fine light sand,

* See Phil. Trans. num. 228.

† See Ray's Discourses, p. 232.

which is blown about by the winds, and transported by the rains, leaving bare the roots of large firs, in which the impressions of the axe are still exceedingly apparent. These hills have unquestionably been formed, like downs, by successive accumulations of sand transported by the motions of the sea. Subterraneous trees are also frequent in the marshes of Holland, Friesland, and near Groningen, which abound in turfs.

In the jurisdiction of Bergues-Saint-Winock, Furnes, and Bourbourgh, we find turf at three or four feet below the surface. These beds of turf are generally two feet thick, and are composed of corrupted wood, of entire trees, with their branches and leaves, and particularly of filberds, which are known by their nuts, and the whole is interlaced with reeds and the roots of plants.

What is the origin of these beds of turf, which extend from Bruges through the whole flat country of Flanders as far as the river Aa, between the downs and the high country in the environs of Bergues, &c.? In remote ages, when Flanders was only a vast forest, a sudden inundation of the sea must have deluged the whole country, and, in retiring, deposited all the trees, wood, and twigs, which it had eradicated and destroyed in this lowest territory of Flanders; and this event must have happened in the month of August or September; because we still find the leaves of trees, as well as nuts, on the filberds. This inundation must have taken place long before that province was conquered by Julius Cæsar, since

no mention is made of it in the writings of the ancients *.

In the bowels of the earth we sometimes find vegetables in a different state from that of common turf. For example, in Mount Ganelon, near Compeigne, we find, on one side of the mountain, quarries of fine stones and the fossil oysters formerly mentioned, and, on the other side, we meet with a bed of the leaves of all kinds of trees, and also reeds, the whole blended together and inclosed in mud. When these leaves are stirred, we perceive the same musty odour which we feel on the margin of the sea; and these leaves preserve their odour during several years. Besides, the leaves are not destroyed; for we can easily distinguish their species: they are only dry, and slightly united to each other by the mud †.

"We distinguish," M. Guettard remarks, "two species of turf: the one is composed of marine, and the other of terrestrial plants. We suppose the first to have been formed when the sea covered all those parts of the earth which are now inhabited. The second is supposed to have been superinduced upon the former. According to this system, it is imagined that the currents carried the sea plants into the hollows formed by the mountains, which were elevated above the

* Mem. pour la Subdelegation de Dunkerque, relativement à l'Hist. Nat. de ce Canton.

† Lettre de M. Lescherin à M. de Buffon; Compeigne, 8 Aout, 1772.

waters, and, after being tossed about by the waves, were deposited in the hollows.

"This origin of turf is not impossible: the great quantity of sea plants is sufficient to account for the phænomenon. The Dutch even allege, that the goodness of their turf is owing to the bitumen with which the sea water is impregnated, and that they were formed by sea weeds.

"The turf pits of Villeroy are situated in the valley through which the river Essone runs; and part of this valley extends from Roissy to Escharcon. . . . . . It is even near Roissy that turfs were first dug. . . . . . But those near Escharcon are the best. . . . . .

"The meadows where turf is dug are open and bad: they are filled with rushes, horse-tail, and other plants, which grow in bad soils. These meadows are dug to the depth of eight or ten feet. . . . . . Next to the upper stratum, there is a bed of turf about a foot thick, and impregnated with river and land shells. . . . . .

"This bed of turf, filled with shells, is commonly earthy: those which succeed are nearly of the same thickness, and are always better as we descend. These turfs are of a blackish brown colour, intermixed with reeds, rushes, and other plants. We see no shells in these beds. . . . .

"In masses of turf we sometimes find the stems of willows and poplars, and sometimes the roots of these and similar trees. On the Escharcon side, an oak was discovered at the depth of nine feet. It was black, and almost corrupted.

It crumbled into dust, after being exposed to the air. Another was found, on the Roissy side, between the soil and the turf, at the depth of two feet. Near Eschaɩ.on, the horns of a stag were found three or four feet below the surface. . . . .

"Turfs are perhaps equally abundant in the environs of Etampes, as near Villeroy. These turfs contain but very little moss. Their colour is a fine black. They are heavy, and burn well in an ordinary fire. Good charcoal might be made of them. . . . . .

"The turfs in the neighbourhood of Etampes may be considered as a continuation of those of Villeroy. In a word, all the meadows adjacent to the river of Etampes are probably full of turf. The same remark is applicable to the meadows through which the river Essone runs: these meadows produce the same plants as those of Etampes and Villeroy *."

According to this author, there are in France a number of places from which turf may be obtained, as at Bourneuille, at Croué, near Beauvais, at Bruneval, in the environs of Péronne, in the diocese of Troyes in Champagne, &c. This combustible substance would be a great resource, if it were used in such places as want wood.

There are likewise turfs near Vitri-le-François, and in the morass along the Marne. These turfs are good, and contain great quantities of acorn shells. The marsh of Saint-Gon, in the environs of Châlons, is full of turf, which the

* Mem. de l'Acad. des Sciences, ann. 1761, p 380—397.

inhabitants will soon be obliged to use for want of wood *.

Subterraneous trees are of different species, *viz.* firs, oaks, birch, beech, yew, hawthorn, willow, ash, &c. In the fens of Lincoln, along the river Ouse, and on Hatfield-chace in Yorkshire, these trees stand erect, as if they were growing in a forest. The oaks are extremely hard, and are used in building, where they are said to last long, which I think improbable, as all the specimens I have examined lose their solidity, after being dried and exposed to the air. The ashes are tender, and soon fall into dust. Some of these trees are evidently cut and sawed with instruments; and the hatchets, which are sometimes found along with them, resemble the knives formerly used in sacrifices. Beside trees, we also meet with vast quantities of filberds, acorns, and fir-cones, in many other fens, in England, Scotland, and Ireland, as well as in the marshes of France, Switzerland, Savoy, and Italy †.

For four miles round the town of Modena, whenever the earth is dug to the depth of sixty-three feet, the workmen pierce about five feet more with a boring instrument, through which the water rushes up with such impetuosity, that it fills the wells to the top, almost instanta-

* Note communicated to M. de Buffon, by M. Greignon, Aug. 6, 1777.

† See Phil. Trans. abridg. vol. iv. p. 218, &c

neously. The water in these wells continues perpetually, and is neither augmented nor diminished by rains or drought. What is still more remarkable in this spot, whenever the workmen dig to the depth of fourteen feet, they find the rubbish and ruins of an ancient city, paved streets, houses, and different pieces of Mosaic work. Below this, the earth is solid, and appears not to have been moved. Still lower, however, we find a moist soil, mixed with vegetables; and, at the depth of twenty-six feet, entire trees, as filberds, with nuts upon them, and great quantities of branches and leaves. At twenty-eight feet, there is a stratum of soft chalk, eleven feet thick, mixed with sea shells; and after this we still meet with vegetables, leaves and branches of trees, till we arrive at the depth of sixty-three feet, where there is a stratum of sand mixed with gravel and shells, similar to those which appear on the coasts of Italy. These successive strata lie always in the same order, wherever pits have been dug; and sometimes the boring instrument falls in with the trunks of large trees. which the workmen pierce with great labour: they likewise meet with bones of animals, pit-coal, flints, and pieces of iron. Ramazzini, who relates these facts, thinks, that the gulf of Venice formerly extended beyond Modena, and that this land, in the progress of time, has been gradually formed by the rivers, assisted, perhaps, by inundations of the sea.

" In the territories of the duke of Saxe-Co-

burg, which lie on the frontiers of Franconia and Saxe, and at some leagues from the town of Coburg, were found, at a small depth, whole trees, so completely petrified, that they were as beautiful and hard as agates. Some specimens of them were given by the princes of Saxe to M. Schoepflin, who transmitted two of them to M. de Buffon for the Royal Cabinet. Vases and other beautiful utensils have been made of this petrified wood *."

Wood in its natural state has likewise been found at great depths. M. du Verny, an officer of artillery, sent me some specimens of it accompanied with the following letter: "The town of Fère, in the garrison of which I am stationed, on the 15th of August, 1753, ordered a search to be made for water by means of boring: at thirty-nine feet below the surface, they found a bed of marl, which they continued to pierce for 121 feet: hence, at the depth of 160 feet, they found, at two different trials, the augre filled with marl, intermixed with numerous fragments of wood, which every person easily recognised to be oak. I send you two specimens of this wood. During the succeeding days' operations, they continued to find the same marl, but not so much mixed with wood, as far as the depth of 210 feet, where they ceased to bore †."

"In the territory of Coburg, which is a

* Lettre de M. Schoepflin, Strasbourg, Sept. 24, 1746.

† Lettre de M. Bresse du Verny; La Fère, Nov. 14, 1753.

branch of the house of Saxe, we find," M. Justi remarks, "petrified wood of a prodigious size. In the mountains of Misnia, entire trees have been dug out of the earth, which were converted into very fine agate. The imperial cabinet of Vienna contains many petrifications of this kind. A great log of this wood was sent to the same cabinet: the part which had been wood was changed into a beautiful agate of a grayish black colour; and, instead of bark, the trunk was surrounded with a belt of fine white agate. . . . . .

"The present emperor wished that a method of ascertaining the age of petrifactions might be discovered. . . . . . He ordered his ambassador at Constantinople to ask permission to take up from the Danube one of the piles of Trajan's bridge, which is some miles below Belgrade. This permission being granted, one of the piles was drawn up, which it was imagined would have been petrified by the water. But, after such a lapse of time, it was discovered that the process of petrifaction had made very little progress. Though this pile had remained in the Danube above 1,600 years, the petrifaction had not proceeded above three quarters of an inch, and even less. The rest of the wood was very little altered, and had only begun to be calcined.

"If a just conclusion, with regard to all other petrifactions, could be drawn from this single fact, nature would perhaps require 50,000 years

to change trees, of the size of those found petrified in certain places, into stones. But, in particular situations, many causes may concur in hastening the process of petrifaction. . . . . . .

"At Vienna there is to be seen a petrified log, which was brought from the Carpathian mountains in Hungary. Upon this log the marks of the hatchet, which had been made before its petrifaction, are distinctly visible; and these marks are so little altered by the change the wood has undergone, that we perceive they have been made by a small instrument. . . . . .

"Besides, it appears that petrified wood is not so rare as is commonly imagined; and that, to discover it in many places, requires only the nice eye of a naturalist. Near Mansfield, I saw a great quantity of petrified oak in a place where many people daily pass, without perceiving this phænomenon. Some logs were entirely petrified, and in these we distinctly perceived the rings formed by the annual growth, the bark, the place where they were cut, and all the characters of oak wood *."

M. Clozier, who found different pieces of petrified wood upon the hills in the neighbourhood of Etampes, and particularly on that of Saint Symphorien, imagined that these fragments might have proceeded from some petrified trunks in the mountains. He therefore

* Journal Etranger, mois d'Octobre, 1756, p. 160.

caused pits to be dug in a part of the mountain of Saint Symphorien that had been pointed out to him. After digging several feet deep, he first discovered a petrified root, which led him to the trunk of a tree of the same species.

"This root, from its extremity to its junction with the trunk, was," says M. Clozier, "five feet in length; there were other five roots, but not equally long. . . . . .

"The middling and small roots were not petrified, or at least their petrification was so brittle, that they remained in the sand, where the trunk was in the form of powder or ashes. It is reasonable to think, that, when the process of petrifaction was communicated to these roots, they had been almost corrupted, and that the ligneous parts of which they were composed, being too much separated by petrifaction, could not acquire the degree of solidity necessary to a genuine petrifaction. . . . . . .

"The thickest part of the trunk was near six feet in circumference. Its length was three feet ten inches, and its weight was from 500 to 600 pounds. The trunk, as well as the roots, had all the appearance of wood, as the bark, the inner rind, the solid and corrupted wood, the holes of large and small worms, and even the excrements of these worms. All these parts were petrified, but were not so solid and hard as the ligneous body, which had been perfectly sound when the process of petrifaction commenced. The ligneous body is converted into

a real flint of various colours, which strikes fire with steel, and produces, after being struck or rubbed, a very strong smell of sulphur. . . . . .

"This petrified trunk was bedded in a horizontal direction. . . . . It was covered with more than four feet of earth, and its root was not above two feet below the surface *."

M. l'Abbé Mazéas, who discovered, at half a mile from Rome, a quarry of petrified wood, expresses himself in the following terms:

"This quarry of petrified wood forms a succession of hillocks in the front of Monte-Mario, on the other side of the Tiber. . . . . Of these fragments of wood, irregularly heaped upon each other, some have the appearance of a hard dry earth, which seems not to be fit for the nourishment of vegetables: others are petrified, and have the colour, the brilliancy, and the hardness of the resin, known in the shops by the appellation of *colophanus*. This petrified wood is found in a soil similar to the former, but more moist. Both are perfectly well preserved. The whole are reduced, by calcination, into a true earth; and none of them produce alum, either by the application of fire, or by combining them with the vitriolic acid †."

M. du Monchau, a physician and expert naturalist, has sent me, for the Royal Cabinet, a piece of petrified wood with the following historical account:

* Mem. des Savans Etrangers, tom ii. p. 598—604.

† Ibid. tom v. p. 388.

"The piece of petrified wood, which I have the honour of transmitting to you, was found at the depth of more than 150 feet below the surface. . . . . Last year (1754), when digging a pit in quest of coal, at Notre-Dame-au-bois, a village situated between Condé, Saint Amand, Mortagne, and Valenciennes, we found, about 600 fathoms from Escaut, and after passing three water levels, first seven feet of rock or hard stone, called *tourtia* in the language of colliers; afterwards, when we arrived at a marshy earth, we found, at the depth of 150 feet, as already remarked, the trunk of a tree of two feet in diameter, which lay across the pit, and, of course, we were prevented from measuring its length. It rested upon a large free-stone; and many pieces were cut off from this trunk by the curious. The small fragment I have the honour of sending you was cut off from a specimen given to M. Laurent, a learned mechanic. . . . .

"This wood seemed rather to have been converted into coal than petrified. How could a tree be sunk so deep into the earth? Has the soil in which the tree was found been formerly as low? If that is the case, how could this soil be augmented 150 feet? From whence did all this earth proceed?

"The seven feet of *tourtia* observed by M. Laurent, which exists also in all the coal mines for ten leagues round, have, according to the above supposition, been produced posterior to this accumulation of earth.

"I leave this matter, sir, to your decision:

you are so intimately acquainted with Nature, that none of her mysteries can be long concealed from you; and I have no doubt that you will be able to explain this wonderful phænomenon *."

M. Fougeroux de Bondaroy, of the Royal Academy of Sciences, relates several facts concerning petrified wood, which merit attention.

" All the fibrous stones," he remarks, " which have some resemblance to wood, are not petrified wood. But there are many others which must be recognised as such, especially if we attend to the peculiar organization of vegetables. . . . .

" Facts are not wanting to prove that wood may be converted into stone, with as much ease at least as several other substances which incontestibly undergo this transmutation. But it is difficult to explain how this effect is produced. I hope I may be permitted to hazard some conjectures on the subject, which I shall endeavour to support by facts and observations.

" We find wood which may be considered as only half petrified, and not much heavier than common wood. Specimens of this kind are easily divided into plates, or even into filaments, like certain corrupted timber. Others are more petrified, and have the weight, the hardness, and the opacity of free-stone. Others, whose petrifaction is still more perfect, admit the same po-

* Lettre de M. Dumonchau à M. de Buffon; Douai, Jan. 29, 1755.

lish as marble; while others acquire that of fine oriental agates. I have an excellent specimen sent from Martinico to M. du Hamel, which is converted into a most beautiful sardonix. Lastly, we find wood changed into slate. Among these specimens, there are some which have retained the organization of wood so completely, that we discover with a lens every appearance exhibited in unpetrified wood.

"We have seen some specimens encrusted with a sandy iron ore, and others penetrated with a substance, which, being composed of sulphur and vitriol, makes them approach the state of pyrites. Some of them are, if we may use the expression, larded with a very pure iron ore; and others are traversed by veins of very black agate.

"We find pieces of wood, one part of which is converted into a stone, and the other into agate: the part converted into stone is tender; but the other has the hardness peculiar to precious stones.

"But, how should certain pieces, though converted into hard agate, preserve the distinct characters of organization, as the concentric circles, the insertions, the extremities of the tubes destined to transmit the sap, the bark, the inner rind, and the wood? If the vegetable substance were entirely destroyed, we should only see an agate, without any of the organic characters formerly mentioned. To preserve this appearance of organization, if we suppose that the wood subsists, and that the pores alone are

filled with the petrifying juice, it should appear, that the vegetable parts might be extracted from the agate. But I could never make any progress in this operation: I therefore think, that the specimens in question retain no parts which have preserved the nature of wood. To give perspicuity to my idea, I beg the reader to recollect, that, when a piece of wood is distilled in a retort, the coal which remains after distillation is not a sixth part of the original weight of the wood. When this coal is burnt, we obtain only a small quantity of ashes, which will still diminish after the lixivial salts are abstracted.

"This small quantity of ashes being the only fixed part, the chemical analysis proves, that the fixed parts of a piece of wood are really very trifling, and that the greatest portion of vegetable matter is destructible, and may be gradually carried off, as the wood corrupts.

"Now, if we consider that the greater part of the wood is destroyed, and that what remains is a light earth, and easily permeable by the petrifying juice, its conversion into stone, agate, or sardonix, will not be more difficult to conceive than that of bole, clay, or any other earth. The only difference is, that the vegetable earth preserves the appearance of organization, and the petrifying juice insinuates into its pores, without destroying its original characters *."

Some facts and observations remain still to be added. In August, 1773, at Montigni-sur-

* Mem. de l'Acad. des Sciences, ann. 1759, p. 431—452

Braine, in the district of Challon and jurisdiction of Auxonne, when digging a copper mine, the workmen, at the depth of thirty-three feet, found a tree lying on its side; but the species of it could not be discovered. The superior strata seemed to have never been touched by the hand of man; for, below the soil, there was a bed of eight feet of clay; then ten feet of sand; then a bed of fullers earth about six or seven feet; then another bed of the same mixed with stones; and, lastly, a bed of black sand of three feet. The tree was found in the fullers earth. The river Braine is to the east, and not above a gun-shot from this place. It runs in a meadow eighty feet lower than the site of the copper*.

M. de Greignon informed me, that, on the borders of the Marne, near St. Dizier, there is a bed of pyritous wood, the organization of which is apparent. This bed is situated under a stratum of free-stone, which is covered with a stratum of pyrites, and above the pyrites is a stratum of lime-stone. The bed of pyritous wood lies upon a blackish clay.

He likewise found, in the pits dug for discovering the subterraneous town of Châtelet, instruments of iron with wooden handles. He remarked that this wood was converted into a genuine iron ore, of the hematites species. The organization of the wood was not destroyed; but it was brittle, and its whole texture was as

* Lettre de Mad. la Comtesse de Clermont-Montoison à M. de Buffon.

close as that of the hematites. These iron instruments with wooden handles had been buried in the earth sixteen or seventeen hundred years. The conversion of the wood into hematites had been affected by the decomposition of the iron, which had gradually filled all the pores of the wood.

"In the parish of Haux, which is situated between two seas, and about half a league from the port of Langoiran, a point of a rock, of eleven feet high, detached itself from the coast, which was formerly thirty feet high. By its fall it spread over the valley a great quantity of animal bones, or fragments of bones, some of which were petrified. That they are bones is unquestionable; but it is difficult to ascertain the animals to which they belong. The greatest number consists of teeth; some of them perhaps belong to the ox or horse; but, without marking the difference in figure, most of them are larger than the teeth of these animals. There are likewise thigh or leg bones, and a fragment of a stag or elk's horn. The whole are covered with common earth, and situated between two strata of rock. We must suppose that the carcasses of animals have been thrown into a hollow rock, and, after the flesh had corrupted, a rock of eleven feet high had been formed above them, which would require the operation of many ages. . . . .

"The gentlemen of the Academy of Bourdeaux, who examined these bones with philosophical accuracy, discovered, that when a number

of fragments were put on a very brisk fire, they were converted into a fine Turquois blue; and that some portions became so hard, that, when cut by a lapidary, they received a fine polish. . . . . . It must also be remarked, that bones which evidently belonged to different animals were equally converted into Turquois*."

"On the 28th of January, 1760," says M. de Guettard, "there were found, 160 fathoms above the mineral baths, bones included in a rock with a gray surface. This rock was neither laminated nor consisted of separate strata, but was one continued mass of stone. . . . .

"After having, by means of gunpowder, penetrated five feet deep into this rock, we found a great number of human bones belonging to every part of the body, as jaw-bones with their teeth, bones of the arms, thighs, limbs, ribs, rotulæ, &c., jumbled together in the greatest disorder. Entire skulls, or portions of them, chiefly prevailed.

"Besides these human bones, we met with several fragments which could not be ascribed to man. In some places, they are in continued masses, and in others more dispersed. . . . .

"When we arrived at the depth of four feet and a half, we found six human heads in an inclined position. In five of these heads, the occiput with its appendages, except the bones of the face, were preserved. This occiput was partly encrusted with stone, its cavity was filled

* Hist. de l'Acad. des Sciences, ann. 1719, p. 24.

with stone, and had assumed the same mould or figure. In the sixth head, the face is entire: it is broad in proportion to its length. We easily distinguish the form of the fleshy cheeks. The eyes are shut, pretty long, but narrow. The front is large, and the nose very flat, but well formed; the middle line is distinguishable. The mouth is well made, and shut; the upper lip is a little thick in proportion to the under. The chin is well proportioned, and the whole muscles are strongly marked. The colour of the head is reddish, and resembles those of the Tritons feigned by painters. Its subtance is similar to that of the stone in which it was found; it is, properly speaking, only the mask of the natural head."

The above relation was sent by M. le Baron de Gaillard-Lonjumeau to Madame de Boisjourdain, who transmitted it to M. Guettard, with some specimens of the bones. That these bones were really human, is a very doubtful point; "for every appearance in this quarry," M. de Lonjumeau remarks, "announces that it has been formed of relics of bodies broken in pieces, and which had been long tossed about by the waves of the sea before they were collected into one heap. As this mass of bones lies horizontally, and has been successively covered with stony matter, it is easy to conceive how a mask was formed on the faces of those heads, the flesh having little time to corrupt, especially when the bodies were buried under

the water. We may, therefore, reasonably conclude, that these heads were not human. . . . . They rather seem to be the heads of those fishes, whose teeth are found in the same parts of the stones along with the bones supposed to belong to the human species.

" It appears that the collection of bones in the environs of Aix, are similar to those discovered some years ago, by M. Borda, near Dax in Gascony. The teeth discovered at Aix, by the description given of them, seem to resemble those found at Dax, of which an under jaw is still preserved. This jaw unquestionably belongs to a large fish. . . . . . I must, therefore, conclude, that the bones in the quarry of Aix are similar to those discovered at Dax; . . . . and that these bones, whatever they are, should be referred to the skeletons of fishes rather than to those of man. . . . . .

" One of the heads in question was about seven and a half inches long by three and some lines broad. Its figure is that of an oblong globe, flat at the base, thicker at the posterior than the anterior end, and divided in the broadest part by seven or eight bands from seven to twelve lines wide. Each band is likewise divided into two equal parts by a slight furrow. The bands extend from the base to the summit. Those of one side are separated from those of the other by another and deeper furrow, which gradually enlarges from the anterior to the posterior part.

"From this description we cannot recognise the mould of a human head. The bones of a man's head are not divided into bands. The human head is composed of four principal bones, the figures of which appear not in the mould above described. It has not an anterior crest which extends longitudinally from the anterior to the posterior part, and divides into two equal parts, which might give rise to the furrow on the superior part of the stony mould.

"These considerations induce me to think, that this substance is rather the body of a nautilus than a human head. There are nautili actually divided into bands or bucklers like this mould. They have a channel or furrow which runs along the whole curvature, and divides them into two, from which the stony furrow might derive its origin*," &c.

I am persuaded, as well as M. le Baron de Lonjumeau, that these heads never belonged to men, but to animals of the seal kind, to sea-otters and to sea-lions or bears. It is not at Aix or Dax alone, that the heads and bones of these animals are found in rocks and caverns. His highness the present prince Marcgrave of Anspach, who to great affability unites a remarkable taste for knowledge, has been so obliging as to give me, for the Royal Cabinet, a collection of bones from the caverns of Gaillenrente in his Marcgraviate of Bareith. M. Daubenton has compared these bones with those

* Mem. de l'Acad. des Sciences, ann. 1760, p. 209—218.

of the common bear, from which they differ only by being larger. The head and teeth are longer and thicker; and the muzzle is longer and more protuberant than in our largest bears. In this collection, with which this noble prince has enriched our cabinet, there is a head which naturalists have denominated, *the head of M. de Buffon's small seal;* but, as we know not the form and structure of the heads of sea-lions, bears, and large and small seals, we shall suspend our judgment concerning the animals to which these fossil bones have appertained.

I will insist no longer upon the varieties in the composition of new strata. It is sufficient to have shown that they have been produced by no other cause than the waters which run or are stagnant upon the surface, and that they are neither so hard nor so solid as the ancient strata which were formed under the waters of the ocean.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE XIX.

Of the Changes of Land into Sea, and of Sea into Land.

FROM what has been remarked in article i. vii. viii. and ix., it is apparent, that the terrestrial globe has undergone some great and general changes; and it is equally certain, from what has been delivered in the other articles, that the surface of the earth has suffered particular alterations. Though we are not sufficiently acquainted with the order or succession of these particular changes, we know the principal causes by which they were produced. We can even distinguish their different effects; and, if we were able to collect all the facts which natural and civil history afford concerning the revolutions that have happened on the surface of the earth, our theory would unquestionably receive

additional supports, and would be rendered still more satisfactory.

One of the principal causes of these revolutions is the motion of the sea, which has continued invariably the same in all ages; for, as the sun, the moon, the earth, the waters, the air, &c., have existed from the moment of creation, the effects of the tides, of the motion of the sea from east to west, of the currents, and of the winds, must have been felt for an equal time: and, even supposing the axis of the globe to have formerly had a different inclination, and that the continents, as well as the seas, were differently disposed, the motions of the ocean, and the causes and effects of the winds, would have remained unaltered. In whatever part of the globe the immense quantities of water which fill the ocean were collected, they would be subject to the same motions.

It was no sooner suspected that our continent might formerly have been the bottom of the sea, than the fact became incontestible. The spoils of the ocean found in every place, the horizontal position of the strata, and the corresponding angles of the hills and mountains, appeared to be convincing proofs; for, when we examine the plains, the valleys, and the hills, it is apparent, that the surface of the earth has been figured by the waters. When we descend into the bowels of the earth, it is equally evident, that those stones which include sea shells have been formed by sediments deposited by the waters, since the sea shells themselves are impregnated with the

same matter that surrounds them. And, in fine, if we consider the corresponding angles of the hills and mountains, we cannot hesitate in pronouncing, that they received their configuration and direction from currents of the ocean. It is true, that, since the earth was first left uncovered with water, the original figure of its surface has been gradually changing: the mountains have diminished in height; the plains have been elevated; the angles of the hills have become more obtuse; those bodies which have been rolled along by the rivers have received a roundish figure; new beds of tufa, of soft stone, of gravel, &c., have been formed. But every thing has remained essentially the same. The ancient form is still recognisable; and I am persuaded, that every man may be convinced, by his own eyes, of the truth of all that has been advanced on this subject; and that, whoever has attended to the proofs I have given, must be fully satisfied, that the earth was formerly under the waters of the ocean, and that the surface, which we now behold, received its configuration from the currents and movements of the sea.

We formerly remarked, that the principal motion of the sea is from east to west. The ocean, accordingly, seems to have gained from the eastern coasts both of the Old and the New Continent, a space of no less than 500 leagues. For the proofs, we must refer to art. ix., and shall here only add, that the direction of all straits, which join two seas, is from east to west. The straits of Magellan, of Frobisher, of Hudson, of Ceylon, of

the sea of Corea, and of Kamtschatka, lie all in this direction, and appear to have been formed by the irruption of the waters, which, being forcibly pushed from east to west, have opened these passages, where the waters still preserve a stronger current in this than in any other direction; for, in all straits of this kind, the tides are high and violent; but, in those situated on the western coasts, as that of Gibraltar, of Sunda, &c., the motion of the tides is almost imperceptible.

The inequalities at the bottom of the sea change the direction of the motion of the waters. These inequalities have originated from sediments and matters transported by the tides, or by other movements in the water: the tides are the principal and first, though not the only cause, which produced these inequalities. The wind is another cause; though its action begins at the surface, it agitates the whole mass to the greatest depths, as appears from particular bodies which are detached from the bottom of the sea, and thrown ashore during violent storms only.

It has already been mentioned, that, between the tropics, and even some degrees beyond them, an east wind perpetually blows. This wind, which assists the general motion of the sea from east to west, is as ancient as the tides; because it is occasioned by the rarefaction of the air produced by the heat of the sun. There are two combined causes, therefore, the operation of which is greatest in the equatorial regions: 1st, The tides, which are greatest in the southern lati-

tudes; and, 2d, The east winds, which constantly reign in these climates. These two causes have concurred, from the first formation of the earth, in producing a motion in the waters from east to west, and in agitating them more violently in this region of the globe than in any other. It is for this reason that we find between the tropics the greatest inequalities upon the surface of the earth. That part of Africa which lies between these circles, is nothing but a group of different chains of mountains, which generally extend from east to west, as appears from the direction of the great rivers that traverse this unknown region. The same observation holds with regard to the countries both of Asia and America, which lie between the tropics.

The general motion of the sea from east to west, combined with the tides, currents, and winds, produce a variety of effects, both on the bottom of the ocean and on the coasts. Varenius thinks it extremely probable, that gulfs and straits have been formed by reiterated efforts of the ocean against the land; that the gulfs of Arabia, of Bengal, and of Cambaya, have been produced by irruptions of the waters, as well as the straits between Sicily and Italy, between Ceylon and India, between Greece and Eubœa, &c.; that the probability of such irruptions, and of certain lands having been deserted by the sea, is strengthened by the scarcity of islands in the middle of great seas, and by their never appearing there in groups; that, in the immense space occupied by the Pacific Ocean, there are only two or three

small islands near the centre of it; and that, in the vast Atlantic Ocean between Africa and Brasil, we find only the small islands of St. Helena and Ascension: but all islands lie near large continents, as those of the Archipelago, which approach the continents both of Europe and Asia; the Canaries are near Africa; the Indian islands lie near the eastern part of the continent of Asia; the Antilles lie off the coast of America; and the Azores alone lie at a considerable distance both from Africa and America.

The popular tradition among the inhabitants of Ceylon, that their island had been separated from the peninsula of India by an irruption of the sea, is extremely probable. The great number of rocks and shoals between the island of Sumatra and the continent demonstrate their former union. The Malabarians affirm, that the Maldiva islands once made a part of the continent of India; and, in general, we may believe, without hesitation, that all the eastern islands have been separated from continents by irruptions of the ocean *.

The island of Great Britain appears to have been formerly a part of the continent; and that England was once joined to France, the narrowness of the strait, and the sameness of the strata of stone and of earth, on the opposite sides, are a sufficient indication. "If we suppose," says Dr. Wallis, "that France was connected to England

* See Varen. Geogr. p. 203, 217, and 220.

by an isthmus between Calais and Dover, two tides would necessarily strike with violence against each side of it twice every twenty-four hours; and the operation of the sea, both on the east and west of this isthmus, would, in the course of time, gradually cut through such a narrow neck of land. The tides, acting with violence not only against this isthmus, but also against the coasts of France and of England, must have carried away vast quantities of earth, sand, and clay, from every part on which the waves exerted their fury. Their course, however, being interrupted by the isthmus, they would not, as might be imagined, deposit their sediments upon its shores, but would transport and deposit them on the great plain which now forms the marsh of Romney, and is four miles broad and eight long; for no man, who has ever seen this plain, can possibly doubt of its having been formerly covered with the sea, as, without the intervention of the dikes of Dimchurch, a great part of it would still be overflowed by the spring tides.

" The German Sea would act in the same manner against this isthmus and against the coasts of England and Flanders, and would carry its sediments into Holland and Zeland, the soil of which was formerly under the waters, though it is now elevated forty feet above them. On the English coast, the German Sea must have occupied that large valley which commences at Sandwich, runs by Canterbury, Chatham, Chilham, and terminates at Ashford, a space of more than

twenty miles. Here the land is much more elevated than it was in ancient times; for, at Chatham, the bones of an hyppopotamos were found buried at the depth of seventeen feet, and likewise anchors of ships and sea shells.

"Nothing is more apparent than that new lands are formed by the earth, sand, clay, &c., transported and deposited by the sea: for, in the island of Okney, which is adjacent to the marshy coast of Romney, there was a flat space of ground in continual danger of being overflowed by the river Rother; but this flat, in less than sixty years, has been considerably elevated by the accession of fresh matter brought in by every tide. This river has, besides, deepened its channel so much, that its mouth, which, less than fifty years ago, was fordable by men, is now capable of receiving large vessels.

"In the same manner has the bank of sand, which runs obliquely from the coast of Norfolk to that of Zeland, been formed. This bank is the place where the German and French seas encounter since the rupture of the isthmus; and it is here that the waters deposit the earth and sand which they carry off from the coasts. It is even probable that this bank of sand may, in a succession of ages, give rise to a new isthmus *."

"It is extremely probable," says Mr. Ray, "that the island of Great Britain was formerly joined to France: whether it was separated by an earth-

* See Phil. Trans. abridg. vol. iv. p. 227.

quake, by an irruption of the ocean, or by the operation of men, we know not. But the former junction of Britain to the continent is apparent from the identity of the rocks and different strata, at the same elevation, on the opposite coasts; and from the similar extent of the rocks on each side, being both about six miles. The narrowness of this strait, which exceeds not twenty-four English miles, and its shallowness, when compared to the depth of the neighbouring sea, render it probable that England has been separated from France by some accident. To these proofs we might add, that wolves and bears formerly existed in this island: it is not probable that these animals could swim over, nor that such destructive creatures would be transported by men; for, in general, the noxious animals of the continent are found in all those islands which are very near it, but never in those that are remote. This fact was remarked by the Spaniards when they arrived at America *."

In the reign of Henry I. of England, a part of Flanders was overflowed by an irruption of the sea. In 1446, more than 10,000 persons were drowned by a similar irruption in the territory of Dordrecht, and more than 100,000 round Dullart in Friseland and Zeland. In these two provinces, above 300 villages were overflowed. The tops of their towers and spires are still visible above the surface of the water.

From the coasts of France, England, Holland,

* See Ray's Discourses, p. 208.

and Germany, the sea has in many places retreated. Hubert Thomas, in his Description of the Country of Liege, assures us, that the walls of the city of Tongres were formerly surrounded by the sea, though it is now thirty-five leagues distant from that city. He gives several satisfactory reasons: among others, he informs us, that, in his time, the iron rings, to which ships were fastened, still remained in the walls. The fens of Lincoln, of the island of Ely, and the Crau of Provence in France, may be regarded as lands abandoned by the sea, which has likewise, since the year 1665, retired considerably from the mouth of the Rhone. At the mouth of the Arno, in Italy a large quantity of land has been gained from the sea: and Ravenna, which was formerly a harbour, is no longer a sea-port. The whole of Holland appears to be new land; the surface of the ground is nearly on a level with the sea, although it has received daily elevations from the mud and earths transported by the Rhine, the Maese, &c.; for the soil of Holland was formerly, in many places, computed to be fifty feet below the level of the sea.

It has been alleged, that, in the year 860, a furious tempest drove such quantities of sand upon the coast, that the mouth of the Rhine near Catt was entirely blocked up; and that this river overflowed the whole country, overturned trees and houses, and at last emptied itself into the channel of the Maese. In 1421, another inundation separated the city of Dordrecht from the main land, overwhelmed seventy-

two villages, and drowned 100,000 persons, beside a vast number of cattle. The dike of Issel was broken down in 1638, by the ice from the Rhine blocking up the passage of the water, which occasioned an opening in the dike of several fathoms, and a great part of the province was laid under water before the breach could be repaired. The province of Zeland, in 1682, suffered a similar inundation, which drowned more than thirty villages; and an amazing number of men and cattle perished, as the unfortunate event happened during the night. The loss would have been still greater, had not a south-east wind opposed the motion of the waves; for there was such a swell in the sea, that the water rose eighteen feet above the highest ground in the province *.

The harbour of Hithe, in the county of Kent, is entirely blocked up, notwithstanding much labour and expense bestowed, on different occasions, to clear it from rubbish. For several miles round, we find an astonishing quantity of shells and other sea bodies, which had been accumulated in ancient times, and which are now covered with soil, and afford excellent pasturage. The sea, on the other hand, often encroaches upon the land. The lands of Goodwin, for example, which formerly belonged to a nobleman of that name, are now converted into sands, and are covered with the waters of the ocean. Thus the sea gains upon some coasts, and loses

* See les Voyag. hist. de l'Europe, tom v. p. 70.

upon others, according to their different situations and circumstances *.

Upon Mount Stella, in Portugal, there is a lake, in which are found the wrecks of ships, though this mountain is twelve leagues distant from the sea †. Sabinius, in his commentary upon Ovid's Metamorphoses, tells us, that, in the year 1460, a ship, with its anchors, was found in one of the Alpine mines.

These changes of sea into land, and of land into sea, are not peculiar to Europe. The other parts of the globe, if properly investigated, would furnish more striking and numerous examples.

Calecut was formerly a celebrated city, and the capital of a kingdom of that name. It is now reduced to an inconsiderable town, ill built, and almost deserted. The sea, which, for a century past, has gained greatly upon this coast, now covers most of the ancient city. Ships moor upon its ruins, and the port is choked up with a number of rocks, upon which many vessels have been wrecked ‡.

The province of Jucatan, a peninsula in the gulf of Mexico, was formerly a part of the sea. This neck of land stretches about 100 leagues in length, and is no where above twenty-five leagues broad. The air is hot and moist. The earth furnishes plenty of water, though, in so large a country, there are neither rivers nor brooks; and, when pits are dug, such multitudes

* See Phil. Trans. abridg. vol. iv. p. 234.

† See Gordon's Geog. Gram. p. 149.

‡ See Lettres Edifiantes, recueil ii. p. 187.

of shells every where appear, as leave no room for doubting that this whole tract of land was formerly a part of the ocean.

It is a tradition among the inhabitants of Malabar, that the Maldiva islands originally belonged to the continent of India, and that they were detached from it by the violence of the ocean. The number of these islands is so great, and they are separated by such narrow channels, that the bowsprits of vessels, in passing, drive off leaves from the trees on each side; and, in some places, a vigorous man, by laying hold of a branch, may leap into another island *. The cocoa trees, found at the bottom of the sea, are a farther proof that the Maldivas formerly belonged to the continent.

The island of Ceylon, those of Rammanakoiel, and many other islands, it is believed, were also disjoined from the continent by currents, which, in many places of the Indian Sea, are extremely rapid †. It is certain, however, that the sea has encroached thirty or forty leagues on the north-east coast of Ceylon.

The sea appears to have lately abandoned many of the promontories and islands of America. We have already remarked, that the territory of Jucatan is full of shells. The same phænomenon takes place in the low grounds of Martinico and the other Antilles. The inhabitants distinguish

* See Voyages des Hollandois aux Indes Orientales, p. 274.
† Ibid. vol. iv. p. 485.

the earth below the surface by the name of *lime;* because they make lime of the shells, great banks of which lie immediately under the vegetable soil *.

There are some lands which the sea alternately covers and leaves bare, as happens in several islands of Norway, Scotland, the Maldivas, the gulf of Cambaya, &c. The Baltic Sea has gradually gained a great part of Pomerania; and it has covered and destroyed the celebrated port of Vineta. In the same manner, the Norwegian Sea has advanced into the continent, and formed several islands. The German Sea has encroached upon Holland, near Catt, to such a degree, that the ruins of an ancient Roman citadel, which was formerly situated on the coast, lie now at a considerable distance in the sea. The marshy ground in the island of Ely, and the Crau of Provence, are, on the contrary, lands which the sea has deserted. The Downs have been formed by accumulations of sand, earth, and shells successively driven upon the coasts by winds blowing from the sea. For example, on the west coasts of France, Spain, and Africa, a violent west wind reigns, by which the waters are pushed with violence against the shores; and downs, accordingly, are frequent on these coasts. The east winds, in the same manner, when they continue long, drive the waters so forcibly from the coasts of Syria and Phœnicia, that large chains of rocks,

* See Nouv. Voyages aux Isles de l'Amerique.

which are covered during the west winds, are left dry. Besides, downs are not composed of stones and marble, like the mountains which have been formed in the bottom of the ocean, because they have not remained long enough under the waters. That the waters of the sea possess a petrifying power, and that the stones formed in the earth are very different from those formed at the bottom of the ocean, is fully evinced in my discourse on minerals.

In traversing the coasts of France, we perceive that a part of Brittany, Picardy, Flanders, and Lower Normandy, have very recently been deserted by the sea; because, through all this extent of country, we still find great quantities of oysters, and other shells, in their natural state. We are certain, from experience, that, for a century past, the sea has been retiring from the coast of Dunkirk. When the moles of this port were constructing, in the year 1670, the fort of Good Hope, which terminates one of these moles, was built upon piles a great way beyond the low water mark. But, at present, the water never advances nearer this fort than 300 fathoms. In 1714, when the new harbour of Mardik was deepening, the moles were likewise carried beyond the low water mark; but now, when the tide is ebb, there is a dry space of more than 500 fathoms. If the sea continues thus gradually to retire, Dunkirk, like Aiguemortes, will, in a few centuries, be no longer a sea-port. If the sea has lost ground so considerably in our times,

how far must it have retired since the beginning of the world? *

The bare inspection of Saintonge is sufficient to convince us, that it was formerly covered by the sea. The ocean having abandoned these lands, the Charente followed as the waters retired, and formed a river where formerly there was only a great lake or morass. The country of Aunis, which was anciently covered by the sea and stagnant waters, is one of the most recent lands of France. It is even probable that this territory was a morass about the end of the fourteenth century †.

It appears, therefore, that the ocean, during some centuries, has retired many feet from all our coasts; and, if we examine those of the Mediterranean, from Roussillon to Provence, we shall find that this sea has likewise retreated nearly in the same proportion. These facts render it evident, that the circumference of all the coasts of Spain and Portugal, as well as those of France, is greatly extended. The same observation has been made with regard to Sweden, where some philosophers have conjectured, that, in the course of 4,000 years, the Baltic, the depth of which exceeds not thirty fathoms, will be totally abandoned by the waters.

If similar observations were made in every

* Mem. pour la Subdelegation de Dunkerque, relativement à l'Hist. Nat. de ce Canton.

† Extrait de l'Hist. de la Rochelle, art. ii. et iii.

country, I am persuaded, that, in general, the sea would be found to have retired from every coast. The same causes which produced its first retreat and successive sinking, are not absolutely annihilated. In the beginning, the sea was 2,000 fathoms above its present level. The immense swellings on the surface of the globe, which first subsided, made the waters sink, at first rapidly, and afterwards in proportion as the more inconsiderable caverns gave way. The sea, of course, was proportionally depressed; and, as many caverns still exist, which must, from time to time, sink, either by the action of volcanos, by the force of water, or by earthquakes, we may with certainty predict, that the ocean will continue to retire, and, consequently, that the extent of all our continents will be gradually augmented.

Since finishing my Theory of the Earth, which was composed in the year 1744, I have perused M. Barrere's Dissertation on the Origin of figured Stones. It gave me peculiar satisfaction to find that the ideas of this accomplished naturalist, concerning the formation of downs, and the duration of the sea upon the surface of the earth which we inhabit, exactly corresponded with my own. Aiguismortes, which is now more than a league and a half from the sea, was a port in the time of St. Louis. Psalmodi was an island in the year 815; and it is now more than two leagues from the sea. The same change has happened at Maguelone. The greatest part of the vineyard of Agde was covered, about

forty years ago, with the waters of the sea. In Spain, the sea, within these few years, has retired considerably from Blanes, from Badalona, from the envirous of the river Vobregat, from Cape Tortosa, along the coast of Valencia, &c.

The sea may form hills and mountains, 1. By transporting earth, slime, sand, and shells from one place to another. 2. By depositing sediments composed of small particles detached from the bottom and from the coasts. And, *lastly*, hills and downs may be formed by sand and other particles driven against the coasts by particular winds; these are gradually deserted by the sea, and become parts of the dry land. The downs of Flanders and Holland are of this kind. They consist of small elevations or hills, composed of sand and shells which have been blown from the sea upon the coasts. M. Barrere gives another example, which merits observation. "The sea," he remarks, "by its motion, detaches immense quantities of plants, sand, shells, and slime, from its bottom, which are continually pushed by the winds and the waves towards the coasts. The perpetual repetition of this operation must give rise to gradual accumulations of new strata, which elevate the earth, produce downs and hills, enlarge the land, and confine the sea within narrower bounds.

"It is apparent that new strata of different materials must have been formed by the constant attrition of the waters, by the deposition of sediments, and by other causes, the operation of which has been coëval with the existence

of the globe itself. Of this we have a remarkable proof in the different strata of fossil shells, and other sea bodies, found at Roussillon near the village of Naffiac, which is seven or eight leagues from the sea. These beds of shells, which incline at different angles from west to east, are divided from each other by strata of earth and sand sometimes of a foot and a half, and sometimes of two or three feet in thickness. In dry weather they seem as if sprinkled over with salt, and form a chain of hillocks, from twenty-five to thirty fathoms high. A long chain of hillocks of such a height could not be formed at once, but gradually, and by a long succession of time. Effects somewhat similar might have been produced by an universal deluge. But, in this case, the different beds of fossil shells, instead of preserving a regular form, would have been blended together without any order."

I entirely agree with the sentiments of M. Barrere, except as to the formation of mountains, which cannot be ascribed solely to those causes which increase the land and diminish the boundaries of the ocean. On the contrary, I can produce several convincing arguments to prove, that most of those eminences, which appear on the surface of the earth, have actually received their original formation in the sea itself: 1. Because they have corresponding angles, which necessarily imply the cause we have assigned, namely, the motion of the currents. 2. Because downs and hills, which have originated

from materials thrown upon the coasts, are not, like common hills, composed of marble and hard stones. Besides, the shells found in the former are only in the fossil state; but those in the latter are entirely petrified. Neither is the position of the strata equally horizontal in downs, as in the hills composed of marble and hard stone. They are more or less inclined, as in the hills of Naffiac. On the contrary, in the hills and mountains formed by sediments under the waters of the sea, the strata are always parallel, and often horizontal; and the shells and other matter of them are completely petrified. I despair not of being able to prove, that the marbles and other calcarious bodies, which are almost all composed of madrepores, astroites, and shells, have acquired their density and perfection at the bottom of the ocean. But the tufas, soft stones, incrustations, stalactites, &c., which are likewise calcinable, and have been formed since the earth was left dry, can never acquire the degree of density and of petrifaction peculiar to marble and other hard stones.

The remarks of M. Saulmon, concerning the *galets*, which are found in many places, may be seen in the History of the French Academy, *anno* 1707. These galets are round, flat, finely polished pieces of flint, thrown out by the sea upon the coasts. At Bayeux, and at Prutel, which is a league from the sea, galets are found in digging pits and wells. The mountains of Bonneuil, of Broie, and of Quesnoy, which are eighteen leagues distant from the sea, are co-

vered with galets. They are also found in the valley of Clermont in Beauvois. M. Saulmon farther informs us, that a hole, sixteen feet in length, was pierced horizontally into the high beach of Tresport, which consists of a soft earth; and that, in the space of thirty years, it was entirely obliterated by the sea. Supposing the sea to encroach uniformly upon this shore, it will gain half a league in 12,000 years.

The motions of the sea, therefore, must be regarded as the principal cause of all those changes which have already happened, and of those which are daily produced upon the surface of the earth. But there are other causes, which, though less considerable, have some effect in changing the superficial parts of this globe. The rivers, the brooks, the melting of snows, the torrents, the frosts, &c., have given rise to many alterations. The rains have diminished the height of the mountains; the rivers and brooks have elevated the plains, and dammed up the sea at their mouths; the torrents and the melting of snows have scooped out deep ravines or furrows in the valleys and narrow passages between the mountains; the frosts have split rocks, and detached them from their original stations: innumerable examples of revolutions produced by all these causes might be given. Varenius tells us, that the rivers transport into the sea vast quantities of earth, and deposit them at greater or lesser distances from the shore, in proportion to the rapidity of their currents. These portions

of earth fall to the bottom, and first form small banks, which, by constant accessions, become shoals, and at last appear in the form of fertile and habitable islands. It is in this manner that the islands in the Nile, those in the river St. Lawrence, the island of Landa, situated near the mouth of the river Coanza, on the coast of Africa, the Norwegian islands, &c., have received their existence *. To these may be added the island of Trong-ming in China, which has been gradually formed by matters brought down by the river Nankin, and deposited near its mouth. This island is more than twenty leagues in length, and from five to six in breadth †.

The Po, the Trento, and other rivers of Italy, bring down such quantities of earth into the *lagunes* of Venice, especially in the time of inundations, that they must be gradually filled up. Many parts of them are already dry during the ebb tide; and there is in them no depth of water, except in the canals, which are supported at an immense expense.

Large sand-banks are thrown up at the mouths of the Nile, of the Ganges, of the Indus, of the Plata, and of many other rivers. La Loubere, in his voyage to Siam, informs us, that the banks of sand and of earth augment daily at the mouths of the great rivers of Asia, and to such a degree, that the navigation of them

* See Varen. Geogr. p. 214.

† See Lettres Edifiant. rec. xi. p. 234.

becomes every hour more difficult, and will soon be impracticable. The same observation applies to the great rivers of Europe, and especially to the Wolga, which empties itself by more than seventy mouths into the Caspian, and to the Danube, which runs into the Black Sea by seven mouths, &c.

As it seldom rains in Egypt, the regular inundations of the Nilé proceed from the torrents which fall into it from Ethiopia. It brings down vast quantities of mud, which it deposits annually not only upon the soil of Egypt, but throws it to great distances into the sea, where it is laying the foundations of a new country, which must arise, in the course of time, out of the bosom of the ocean; for, upon sounding at the distance of twenty leagues from the coast, the mud of the Nile is found at the bottom of the sea; and every year it receives fresh accumulations. The Lower Egypt, now called the Delta, was formerly a bay *. Homer tells us, that the island of Pharos was a day and a night's voyage from Egypt; and now it is almost contiguous to the land. The soil of Egypt is not every where of an equal depth; it grows thinner the farther we remove from the sea. Near the banks of the Nile, there are sometimes more than thirty feet of good soil; but at the extremity of the inundation, there are not, perhaps, above seven

* See Diodor. Sic. lib. iii. Aristot. de Meteor. lib. i. cap 14. Herodot. § 4. 5, &c.

inches. All the cities of the Lower Egypt have been built upon artificial eminences *. The town of Damietta, which is now ten miles from the sea, was a part of the ocean in the year 1243. The town of Fooah, which, 300 years ago, was situated at the mouth of the Canopic branch of the Nile, is now seven miles distant from it. Within forty years, the sea has retired half a league from Rosetta, &c. †

Many changes have also taken place at the mouths of the great rivers of America, and even in those which have been but lately discovered. Charlevoix tells us, "that at the mouth of the Missisippi, below New Orleans, the land runs out into a point, which appears not to be very ancient; because, wherever the earth is dug, plenty of water is found; and besides, the many little islands, which have recently appeared in all the mouths of this river, leave no room to doubt that this point of land was formed in the same manner. It is certain," says he, "that when M. Salle sailed down the Missisippi to the sea, the mouth of this river was considerably different from what it is now.

"The nearer," he adds, "we approach the sea, this difference becomes the more conspicuous. There is no water in most of the small channels cut in the bar by the river. These channels are greatly multiplied by the trees brought down by the current. A single tree, with its branches

* See Shaw's Travels. † Ibid.

and roots, when stopped in a shallow part of the river, will entangle a thousand. I have seen," says he, "200 leagues from New Orleans, different collections of trees, any one of which would fill all the wood-yards in Paris. Nothing can disentangle them. The mud brought down by the river serves as a cement, and gradually covers them. Every inundation leaves a new stratum; and, in a few years, plants and shrubs begin to grow." It is in this manner that most points of land and islands, which so often change the course of rivers, are originally produced.

All the revolutions, however, produced by rivers, are very slow, and become not considerable till after a long course of years. But those which are occasioned by inundations or earthquakes are sudden and almost instantaneous. According to the Timæus of Plato, we are assured, by the ancient priests of Egypt, 600 years before the birth of Christ, that there existed an island beyond the Pillars of Hercules, called Atlantis, which was larger than both Asia and Lybia taken together; and that this great island was sunk under the waters of the ocean by a terrible earthquake. "Traditur Atheniensis civitas restitisse olim innumeris hostium copiis quæ, ex Atlantico mari profectæ, propè cunctam Europam Asiamque obsederunt; tunc enim fretum illud navigabile, habens in ore et quasi vestibulo ejus insulam quam Herculis Columnas cognominant: ferterque insula illa Lybiâ simul et Asiâ

Major fuisse, per quam ad alias proximas insulas patebat aditus, atque ex insulis ad omnem continentem è conspectu jacentem vero mari vicinam; sed intrà os ipsum portus angusto sinu traditur, pelagus illud verum mare, terra quoque ille verè erat continens, &c. Post hæc ingenti terræ motu jugique diei unius et noctis illuvione factum est, ut terra dehiscens omnes illos bellicosos absorberet, et Altantis insula sub vasto gurgite mergeretur."—*Plato in Timæo.* This ancient tradition is not devoid of probability. The lands swallowed up by the waters were, perhaps, those which united Ireland to the Azores, and the Azores to the continent of America; for, in Ireland, there are the same fossils, the same shells, and the same sea bodies, as appear in America, and some of them are found in no other part of Europe.

Two evidences are mentioned by Eusebius on the subject of deluges: the one is Melo, who affirms, that all the plains of Syria were formerly laid under water: the other is Abidenus, who says, that, in the reign of king Sisithrus, there was a great deluge, which had been predicted by Saturn. Plutarch, *De Solertia Animalium*, Ovid, and other mythologists, describe the deluge of Deucalion, which happened, they say, in Thessaly, about 700 years after the universal deluge. It is also alleged, that there was a still more ancient deluge in Attica, during the time of Ogiges, about 230 years before that of Deucalion. In the year 1095, a deluge in Syria

drowned a prodigious number of people*. In 1164, a deluge in Friesland covered the whole environs of the coasts, and drowned several thousands of the inhabitants†. Another inundation, in 1218, destroyed 100,000 men. Of inundations there are many other examples.

Impetuous winds may be regarded as a third cause of changes on the surface of the globe. They not only give rise to downs and hills along the sea-coasts, but they often arrest rivers, make them regorge, and change their directions. They carry off cultivated lands, tear up trees, overturn houses, and cover whole countries with sand. Upon the coast of Brittany, in France, we have an example of these inundations of sand: the History of the Academy, *anno* 1722, describes it in the following terms:

"In the environs of St. Paul de Leon, in Lower Brittany, there is a province on the sea-coast, which, before the year 1666, was inhabited; but now is totally deserted, on account of the sand, which has covered it to the depth of twenty feet, and which daily gains ground. Reckoning from the above period, the sand has advanced about six leagues into the country; and it is now within half a league of St. Paul, and that town must probably soon be deserted. The tops of steeples, and of some chimneys, still appear above this ocean of sand. The inhabitants, however, have always had leisure to quit their possessions in safety." p. 7.

* See Alsted. Chron. chap. 25. † See Krank, lib. v. c. 4.

" This calamity is augmented by an east, or a north wind, which elevates this fine sand, and carries it in such quantities, and with such rapidity, that M. Deslandes, to whom the Academy are indebted for the observation, when walking in this country during an east wind, found himself obliged to shake his hat and his garments from time to time, on account of the great weight of sand with which they were loaded. Besides, when the wind is violent, it carries the sand over a small arm of the sea, as far as Roscof, a port much frequented by foreign vessels; and the sand accumulates in the streets of this village to the height of two feet, which obliges the inhabitants to drive it off in waggons. It may be farther remarked, that the sand is mixed with ferruginous particles, which are recognisable by the magnet.

" The coast which furnishes this sand extends from St. Paul to Plouefcat, a space of more than four leagues; and it is nearly on a level with the sea when the tide is full. It is situated in such a manner that the east and north-east winds only can blow the sand in upon the country. It is easy to conceive how sand carried and accumulated into any place by the wind, may again be taken up by the same wind, and carried still farther. Thus the sand may continue advancing, and covering new land, as long as the magazine from which it originally proceeds shall remain unexhausted; for, if the fountain were once dried up, the sand, by advancing, would diminish in depth, and its destructive

consequences would gradually decay. But it is not improbable that the sea may long continue to supply fresh sand, and keep this baneful magazine in a condition to do perpetual mischief.

"This disaster is not of an old date. Perhaps it was not till lately that the place was sufficiently stored to allow great quantities of sand to be carried off; or, perhaps, it has but recently been left uncovered by the waters. This coast has undergone some change. At present, the sea, at full tide, reaches half a league on this side of certain rocks, which it formerly never passed.

"This miserable province justifies what has been related, both by ancient and by modern travellers, that whole cities, and even vast armies, have been buried by tempests of sand in the deserts of Arabia."

Mr. Shaw relates, that the ports of Laodicea, Tortosa, Rowadsa, Tripoly, Tyre, Acra, and Jaffa, are blocked up with sand transported by the high waves which rise on that part of the coast of the Mediterranean, when the west wind blows with violence *.

It is needless to give more examples of alterations on the surface of this globe. The fire, the air, and the waters, produce continual changes, which, in a succession of ages, become considerable. The sea and the land not only change places from the effects of general and

* See Shaw's Travels.

stated periodic laws, but a number of revolutions are occasioned by particular and accidental causes, as earthquakes, inundations, sinkings of mountains, &c. Thus the surface of the earth, which we regard as the most permanent of all things, is subjected, like the rest of nature, to perpetual vicissitudes.

CONCLUSION.

FROM the proofs delivered in art. vii. and viii., it appears to be an established fact, that the whole surface of what is now dry land, was formerly buried under the waters of the ocean. It is equally clear, from art. xii., that the flux and reflux, and other movements of the ocean, perpetually detach from the coasts, and from the bottom of the sea, shells, and matter of every species; and that these are deposited in other places in the form of sediments, and give rise to the horizontal strata which every where appear. In the ixth art. we have proved, that the inequalities on the surface of the globe have been occasioned by the motion of the waters of the sea; and that the mountains received their original formation from successive accumulations of sediments. It is likewise evident, from art. xiii , that the currents, which first followed the direction of these inequalities, afterwards bestowed on them their present figure, namely, their alternate and corresponding angles. From art. viii. and xviii. it appears, that most of the matters detached from the coasts

and from the bottom of the sea, were, when deposited in sediments, in the form of a fine impalpable powder, which entirely filled the cavities of shells, whether this powder was of the same nature, or only analogous to the matter of which the shells were composed. It is undeniable, from art. xvii., that the horizontal strata, which have been formed by successive accumulations of sediments, and which at first were soft and ductile, acquired density and compactness in proportion as they dried; and that the perpendicular fissures in the strata derived their origin from the act of drying.

After perusing art. x. xi. xiv. xv. xvi. xvii. xviii. and xix. we must be convinced, that the surface of the earth has been disfigured by many revolutions and particular vicissitudes, arising from the operation of the waters, and the effects of rains, frost, rivers, winds, subterraneous fires, earthquakes, inundations, &c., and, consequently, that the sea has alternately changed places with the dry land, especially in the first ages after the creation, when terrestrial substances were much softer than they are at present. It must, however, be acknowledged, that our judgment concerning the succession of natural revolutions cannot fail to be very imperfect; that we are still less competent judges of those changes which owe their birth to fortuitous events; and that the defect of historic records deprives us of the knowledge of particular facts. We desiderate both time and experience. We

never consider, that, though our existence here be extremely limited, Nature proceeds in her course. We are ambitious of condensing into our momentary duration both the past and the future, without reflecting that human life is only a point of time, a single fact in the history of the operations of God.

FACTS AND ARGUMENTS

IN SUPPORT OF THE

COUNT DE BUFFON'S

EPOCHS OF NATURE.

THE treatise composed by the count de Buffon, under the title of *Les Epoques de la Nature*, is exceedingly ingenious. It is intended to establish, by facts and reasoning, his Theory of the Formation of the Planets *. But as this theory, however it may be relished on the continent, is perhaps too fanciful to receive the general approbation of the cool and deliberate Briton, the translator has been advised not to render it into English. Many of the facts, however, are too important to be omitted. Instead of a regular translation, therefore, he shall give a general view only of the positions laid down in this treatise, together with the most interesting facts produced in support of these positions.

* See vol. i. p. 59 of this work.

The count de Buffon begins his subject with a preliminary discourse, in which he endeavours to unfold the different changes the terrestrial globe has undergone from its first projection out of the sun to the present time. In this discourse, the author observes the following order: 1. He mentions such facts as may lead us to the origin of nature. 2. He marks those monuments which ought to be regarded as the evidences of the first ages. 3. He collects such traditions as may convey some idea of the ages which succeeded. " After which," says he, " we shall endeavour to connect the whole by analogies, and to form a chain, which, from the commencement of time, shall descend to the present days."

FIRST FACT.

The earth is elevated at the equator and depressed at the poles, in the proportion required by the laws of gravity and of the centrifugal force.

SECOND FACT.

The earth possesses an internal heat which is proper to itself, and independent of that communicated to it by the rays of the sun.

THIRD FACT.

The heat conveyed to the earth by the sun is very small when compared with the heat proper to the globe; and this heat transmitted by the sun would not alone be sufficient to support animated nature.

FOURTH FACT.

The materials of which the earth is composed are, in general, of a vitreous nature, and the whole of them may be converted into glass.

FIFTH FACT.

We find on the whole surface of the earth, and even on the mountains, to the height of 1,500 and 2,000 fathoms, an immense quantity of shells and other relics of marine productions.

The first fact, namely, the elevation of the globe at the equator and its depression at the poles, has been mathematically demonstrated and physically proved by the theory of gravitation, and by experiments with the pendulum. The figure of the earth is precisely the same which a

fluid globe revolving round its axis with equal celerity would assume. Hence the matter of which the earth is composed was in a state of fluidity the moment it assumed its form, and this moment happened whenever it began to turn round its own axis. Now, though heat is the general cause of fluidity, since water itself, without heat, would form a solid mass, we have two methods of conceiving the possibility of the primitive fluid state of the earth. The first is the solution of terrestrial matters in water; and the second is their liquefaction by fire. But most of the solid matters of which the earth is composed are not soluble in water; and, at the same time, the quantity of water, in proportion to that of dry and solid matter, is so small, that it is impossible the one could be dissolved by the other. Of course, as this state of fluidity could not be effected by dissolution or maceration in water, this fluidity must have been produced by the operation of fire.

This conclusion assumes a new degree of probability from the second fact, and is rendered certain by the third. The internal heat of the globe, which still subsists partially, and is greater than that afforded by the sun, shows that this primitive fire is not yet nearly dissipated. The surface of the earth is colder than its interior parts. Uncontrovertible and reiterated experiments evince, that the whole mass of the globe has a heat proper to itself, and totally independent of that of the sun. This heat is rendered evident by

comparing our winters with our summers *; and it is still more palpable when we penetrate into the bowels of the earth. At equal depths, it is invariably the same, and it appears to augment in proportion as we descend.

"At no great depth, we perceive a heat which never varies with the temperature of the atmosphere. We know, that the liquor of the thermometer remains, during the whole year, at the same height in the caves of the Observatory, which exceed not eighty-four feet, or fourteen fathoms below the surface. Hence this point has been fixed as the mean temperature of our climate. This heat commonly continues nearly the same, from fourteen or fifteen to sixty, eighty, or one hundred fathoms, more or less, according to circumstances, as we experience in our mines. Beyond this depth it augments, and sometimes becomes so great, that the workmen could not support it, if they were not cooled by fresh air, either from air-pits, or from falls of water. . . . . M. de Gensanne found, that, in the mines of Giromagny, three leagues from Béfort, when the thermometer was carried fifty-two fathoms deep, it stood at ten degrees, as in the caves of the Observatory; that, at 106 fathoms deep, it stood at 10½ degrees; that, at 158 fathoms, it mounted to 15½ degrees; and that, at 222 fathoms, it rose to 18⅛ degrees †."

* See Suppl. tom. i. part i. and particularly the two Memoirs, sur la Temperature des Planetes, Suppl. tom. ii.

† Dissert. sur la Glace, par M. Mairan, p. 60.

"In proportion as we descend into the bowels of the earth," M. de Gensanne remarks, "we perceive a sensible increase of heat. One thousand eight hundred feet below the level of the Rhine, at Huninguen, in Alsace, I found, that the heat was so great as to produce a sensible evaporation from water. A detail of my experiments on this subject may be seen in the last edition of that excellent *Traité de la Glace* composed by my deceased illustrious friend M. Dortous de Mairan †."

"All the rich veins of every species of metal," says M. Eller, "are in the perpendicular fissures of the earth; and the depth of these fissures cannot be ascertained. In Germany, some of them have been traced above 6,000 feet deep. In proportion as the miners descend, they feel that the temperature of the air becomes always hotter †."

Though our deepest mines and pits are inconsiderable excavations, yet the internal heat is more sensibly felt in them than on the surface. We may, therefore, presume, that, if we could penetrate still deeper, this heat would increase, and that the parts near the centre of the earth are hotter than those more distant. This internal heat is likewise apparent from the temperature of the ocean, the waters of which, at equal depths, exhibit nearly the same heat as that of the interior parts of the earth. "Having plunged a ther-

* Hist. Nat. de Languedoc, tom. i. p. 24.

† Mem. sur la Generation des Metaux. Academie de Berlin, ann. 1733.

mometer," M. Marsigli remarks, "into the sea in different places and at different times, it was found that the temperature at ten, twenty, thirty, and one hundred and twenty fathoms, was equally from ten to 10¾ degrees *." On this subject M. de Mairan judiciously remarks, "that the hottest waters, which are at the greatest depth, must, as being the lightest, continually ascend above those that are heavier. Hence, according to Marsigli's observations, the temperature of this immense body of water must be always nearly equal, except near the surface, which is exposed to the impressions of the air, where the water sometimes freezes before it has time to descend by its own weight and coolness †."

Besides, it is easy to show, that the fluidity of the ocean ought not, in general, to be ascribed to the powers of the solar rays; since we learn from experience, that the light of the sun does not penetrate the most limpid water above 600 feet; and, of course, that its heat will not reach above a fourth part of that depth, or 150 feet. The late M. Bouguer, a learned astronomer of the Royal Academy of Sciences, found, that, when sixteen pieces of common glass were applied to each other, and making a thickness of 9½ lines, the light, in passing through these sixteen pieces of common glass, was diminished 247 times. He then placed

* L'Hist. Physique de la Mer, par Marsigli, p. 16.

† Dissert. sur la Glace, p. 69.

seventy-four pieces of the same glass in a tube, and at some distance from each other. When this experiment was made, the sun was fifty degrees above the horizon. A very faint appearance of the sun's disk was still perceptible through these seventy-four pieces of glass. The persons who attended him could likewise perceive, but with difficulty, a feeble light. But, when other three pieces of glass were added to the seventy-four, none of them could distinguish the smallest vestige of light. Hence, if we suppose eighty pieces of the same glass, we have a thickness which will render it perfectly opaque.'

From this analogy between the transparency of glass and water, M. Bouguer found, that, to render sea water, which is the most limpid of all waters, perfectly opaque, a thickness of 256 feet is necessary, provided, by another experiment, the light of a flambeau was diminished in the proportion of fourteen to five in traversing 115 inches of water contained in a tube of nine feet seven inches in length. Hence, according to M. Bouguer, no sensible light can pass deeper than 256 feet in water*.

It appears to me, however, that the conclusion drawn by M. Bouguer is very distant from the truth. His experiments should have been made with masses of glass of different thicknesses, and not with separate pieces applied to each other. I am persuaded that the sun's light would penetrate a greater thickness than

* Essai d'Optique sur la Gradation de la Lumiére, p. 85.

that of these eighty pieces, which formed a thickness of no more than 47½ lines, or near four inches. Now, though these pieces he employed were of common glass, it is certain that a solid mass of the same glass, of four inches thick, would not entirely intercept the light of the sun, especially as I know, by my own experience, that light passes easily through six solid inches of white glass. I believe, therefore, that the thicknesses assumed by M. Bouguer should be more than doubled, and that the light of the sun penetrates 600 feet deep into the waters of the ocean; for there is another inaccuracy in M. Bouguer's experiments. He did not make the light of the sun pass through his tube of nine feet seven inches long: he employed the light of a flambeau, and thence concluded the diminution to be in the proportion of fourteen to five. But I am persuaded, that, if the light of the sun had been employed, this diminution would not have been so great, especially as the light of a flambeau could only pass obliquely, whilst that of the sun, by passing directly, would have penetrated deeper by its incidence alone, independent of its purity and intensity. Thus, taking all circumstances into consideration, it appears, that, to approach the truth as near as possible, we should suppose, that the light of the sun penetrates the sea to the depth of 600 feet, and that its heat reaches 150 feet deep. The light and heat must here be understood as sensible degrees only of these qualities.

That the heat of the sun penetrates not above 150 feet deep in the waters of the ocean, I ascertained by analogy, derived from an experiment which appears to be decisive. With a lens of twenty-seven inches diameter by six inches thick at the centre, I perceived, that, by covering the middle part, the lens burnt only from the circumference as far as four inches thick, and that all the thicker part scarcely produced any heat. I then covered the whole lens, except an inch round the centre, and I found, that, after passing this thickness of six inches of glass, the light of the sun had no influence on the thermometer. Hence I am warranted to presume, that this same light, weakened by 150 feet thick of water, would not produce a perceptible degree of heat.

The light proceeding from the moon is unquestionably a reflected light of the sun. This light, however, has no sensible heat, even when the rays are collected into the focus of a burning-glass. Neither would the light of the sun have any heat after passing through a certain depth of water; because it would then be equally feeble as that of the moon. I am, therefore, persuaded, that, by allowing the rays of the sun to pass through a large tube filled with water, and only fifty feet long, which is no more than a third of the depth I have supposed, this feeble light would produce no effect upon the thermometer, even though the liquor stood at the freezing point. From whence I may conclude, that, though the light of the sun pene-

trates 600 feet in the waters of the ocean, its heat would not reach one fourth part of that depth. All the waters below this point would necessarily freeze, unless there was an internal heat in the earth, which alone can maintain their fluidity. In the same manner it is proved, by experience, that the heat of the solar rays penetrates not above fifteen or twenty feet deep in the earth, since ice is preserved at these depths during the warmest summers. Hence, it is clear, that below the basin of the sea, as well as under the superior strata of the earth, there is a perpetual emanation of heat, which supports the fluidity of the waters, and produces the temperature of the earth. In the interior parts of the earth, therefore, a heat exists, which is proper to it, and which is totally independent of that communicated by the sun.

We might confirm this general fact by a number of particular ones. Every man has remarked, that the snow melts in all places where the vapours of the interior parts of the earth have a free issue, as over pits, covered aqueducts, vaults, cisterns, &c., while in all other places, where the earth, bound up by the frost, intercepts these vapours, the snow not only remains, but, instead of melting, freezes. This circumstance is alone sufficient to show, that these emanations from the internal parts of the earth have a real and sensible degree of heat.

With regard to the fourth fact: after the satisfactory proofs we have given in several articles of our Theory of the Earth, it is apparent,

that the materials of which the globe is composed are of the nature of glass. This general truth, which we can prove by experience, was not altogether unknown to Leibnitz, a German philosopher, whose name will continue to be an honour to his country:

"Sane plerisque creditum et a sacris etiam scriptoribus insinuatum est, conditos in abdito telluris ignis thesauros. . . . . Adjuvant vultus, nam omnis ex fusione SCORIÆ VITRI est GENUS. . . . . . Talem vero esse globi nostri superficiem (neque enim ultra penetrare nobis datum) reapse experimur, omnes enim terræ et lapides igne vitrum reddunt . . . . . nobis satis est admoto igne omnia terrestria in VITRO FINIRI. Ipsa magna telluris ossa nudæque illæ rupes atque immortales silices cum tota fere in vitrum abeant, quid nisi concreta sunt ex fusis olim corporibus et prima illa magnaque vi quam in facilem adhuc materiam exercuit ignis naturæ . . . . . cum igitur omniaque non avolant in auras tandem funduntur, et speculorum imprimis urentium ope, vitri naturam sumant, hinc facile intelliges vitrum esse velut TERRÆ BASIN, et naturam ejus cæterorum plerumque corporum larvis latere. *G. G. Leibnitii* protogæa. *Goettingae*, 1749, p. 4 et 5."

The basis of minerals, of vegetables, and of animals, consists of vitrifiable matter; for all their *residua* may be ultimately converted into glass. The substances called *refractory* by chemists, and which they consider as not fusible, because they resist the action of their furnaces

without being changed into glass, may, notwithstanding, be vitrified by the more intense heat of burning-glasses. Hence all the materials of this globe, at least all those which are known to us, have glass for their basis, and may be ultimately reduced to their primitive state.

We have, therefore, proved the original liquefaction by fire of the whole mass of this globe, agreeably to the most rigorous rules of logic: 1. *A priori*, by the first fact, namely the elevation of the earth at the equator, and its depression at the poles. 2. *Ab actu*, by the second and third fact, namely, the internal heat of the globe which still subsists. 3. *A posteriori*, by the fourth fact, which shows the effect of this action of fire, *i. e.* glass, in all terrestrial substances.

But, though the materials which compose this globe have originally been of a vitreous nature, and may all be reduced to glass, they ought to be distinguished from each other with regard to the different states in which they are found before they are converted into glass by the action of fire. They should, in the first place, be divided into vitrifiable and calcarious substances. The first undergo no change by fire, unless it be pushed to such a degree of intensity as is sufficient to reduce them to glass; but an inferior degree of heat reduces the others to lime. The quantity of calcarious substances, though very considerable, is small when compared to those which are vitrifiable. The fifth fact above laid down, proves, that calcarious bodies have been

formed at a different period, and by another element; and we evidently perceive, that all the matters which have not been produced by the immediate action of the primitive fire, have been formed by the intervention of water; because they are all composed of shells and other relics of marine bodies. Under the class of vitrifiable substances are comprehended pure rock, quartz, sand, free-stone, granite, slates, clays, metals, and metallic minerals. These substances form the genuine basis of the globe, and compose its principal and greatest part. The whole of them have been originally produced by the primitive fire. Sand is nothing but glass in powder; slates, dried clays, pure rock, free-stone, and granite, are only vitreous masses, or vitrifiable sand in a concreted form. Flints, crystals, metals, and most other minerals, are only distillations, exudations, or sublimations of the first matters, all of which unfold their primitive origin and their common nature, by their aptitude of being converted into glass.

But calcarious sand and gravel, chalk, brown free-stone, marble, alabaster, calcarious spatha, both opaque and transparent, in a word, every substance which can be converted into lime, do not at first exhibit their original nature. Though, like all the others, they proceed from glass, calcarious bodies have passed through filtres, which have changed their appearance. They have been formed by water. They are composed entirely of madrepores, shells, and other relics of aquatic animals, which alone

are capable of converting fluids into solids, and of transforming the water of the sea into stone. Common marble and other calcarious stones are composed of entire shells and fragments of shells, of madrepores, astroites, &c., all the parts of which are either still evident, or easily recognisable. Gravel is nothing but broken fragments of marble and calcarious stones, which frost and the action of the air detach from the rocks; and they are equally convertible into lime. Lime may also be made of shells, chalk, and light land-stone. Alabaster, and those marbles which contain alabaster, may be regarded as large stalactites, which are formed at the expense of other marbles and common stones. Calcarious spatha is likewise formed by exudation or distillation from calcarious substances, in the same manner as rock crystal originates from vitrifiable matters. All this may be proved by inspecting these different substances, and by examining attentively the great monuments of nature.

MONUMENT FIRST.

Shells and other productions of the ocean are found on the surface and in the interior parts of the earth: and all the substances called *calcarious* are composed of the remains of these marine bodies.

MONUMENT SECOND.

In examining those shells and other marine productions found in France, Britain, Germany, and all the other parts of Europe, we discover, that most of the animals to which these remains have belonged, are not to be found in the adjacent seas, and that these species either have now no existence, or are to be found only in the southern seas. In the same manner, we see, in slates and other substances, at great depths, impressions of fishes and plants, none of which belong to our climates, and which either do not exist, or are to be met with in southern climates only.

MONUMENT THIRD.

In Siberia, and other northern regions of Europe and Asia, we find the skeletons, tusks, and bones of elephants, hippopotami, and rhinoceroses, in quantities sufficient to convince us, that these animals, which at present can propagate only in the southern regions, formerly existed and propagated in northern countries; and it has been remarked, that these remains of elephants, and other terrestrial animals, are found at inconsiderable depths below the surface. But shells and other marine bodies are buried deep in the interior parts of the earth.

MONUMENT FOURTH.

The tusks and bones of elephants, as well as the teeth of the hippopotamus, are found, not only in the northern parts of our continent, but likewise in those of North America, though the species of the elephant and rhinoceros have now no existence in the New World.

MONUMENT FIFTH.

In the middle of continents, and in places most remote from the sea, we find an infinite number of shells, most of which belong to animals actually existing in the southern ocean, and several others have no known representatives; so that their species seem to have been annihilated by causes till now unknown.

By comparing these monuments with the facts, we at once perceive, that the time when vitrifiable substances were formed is much more remote than that of the formation of calcarious bodies; and may now distinguish four, and even five epochs of the remotest antiquity: the first, when the matter of the globe was in fusion by fire, when the earth assumed its form, and the equator was elevated and the poles depressed by its rotatory motion: the second, when this matter consolidated, and formed the great masses of vitrifiable substances: the third, when the sea

covered the whole land now inhabited, and nourished shell animals, the remains of which have formed calcarious bodies: the fourth, when the waters which cover our continents retired to their proper basins: a fifth epoch, the indications of which are equally clear as the other four, is the time when the elephant, the hippopotamus, and other southern animals, inhabited the regions of the north. This epoch is evidently posterior to the fourth, since the relics of terrestrial animals are found near the surface of the earth, whilst those of marine animals are generally, and even in the same places, buried at great depths.

What, will any man maintain, that elephants, and other animals now peculiar to the south, have formerly inhabited the regions of the north? This fact, however singular and extraordinary it may appear, is not the less certain. Great quantities of ivory have been, and daily are found in Siberia, in Russia, and in other northern countries of Europe and Asia. These tusks of the elephant are found some feet below the earth, or they are exposed by the waters when they break down the banks of rivers. We find tusks and bones of the elephant in so many places, and in such quantities, that they never could be brought into such cold regions by human power. From incontestible and reiterated proofs, we are obliged to acknowledge, that these animals were formerly natives of the north, as they are now of the south. What renders this fact more mar-

vellous and more difficult to explain, we find the remains of those animals, now peculiar to the south of the Old Continent, not only in our northern provinces, but likewise in Canada and other parts of North America. In the Royal Cabinet there are several tusks and many bones of the elephant which were found in Siberia. We have other tusks and bones of the same animal which were found in France; as well as teeth of the hippopotamus discovered in America, near the river Ohio. Hence these animals, which cannot subsist in cold countries, have formerly existed in northern climates. Of course, the frozen zone was at that period equally warm as our torrid zone is at present; for it is impossible that the bodily constitution and real habits of these animals, which are the most permanent and invariable things in nature, should so far change as to bestow the temperature of the rein-deer upon the elephant. Neither can we suppose that these southern animals, which require much heat for their subsistence, could ever live and multiply in northern regions, if the climate were equally cold as it is at present. M. Gmelin, who travelled in Siberia, and there collected many bones of the elephant, supposes that vast inundations in the south had driven the elephants to the north, where they would all perish at once by the rigour of the climate. But this cause is not proportioned to the effect. More ivory, perhaps, has already been brought from the north than all the elephants of India now existing could furnish. Much more will be discovered when the vast deserts of the

north, which are scarcely known, shall be peopled, and the earth cultivated and dug by the hands of man. Besides, it is extremely improbable, that these animals should take the route which is most repugnant to their nature; for, if they were pushed by inundations from the south, why did they not rather fly to the east and west? Why did they fly as far as the sixtieth degree of north latitude, when they might have stopt on the road, or turned aside to more fortunate climates? And how is it possible to conceive, that, by an inundation from the southern ocean, the elephants were chased 1,000 leagues into the Old Continent, and more than 3,000 into the New? It is impossible that an inundation from the Indian ocean should drive the elephants into Canada, or even into Siberia; and it is equally impossible, that they should arrive in such numbers as are indicated by their remains.

Dissatisfied with this explication, I imagined that a more plausible one might be given, and which should perfectly correspond with my theory of the earth. But, before exhibiting my ideas on this subject, I shall, to prevent mistakes, remark,

1. That the ivory found in Siberia and in Canada unquestionably belongs to the elephant, and not to the morse or sea-cow, as some voyagers have pretended. In the northern regions, we likewise find the fossil ivory of the morse; but it is different from that of the elephant; and they are easily distinguished by comparing their internal texture. The tusks,

the grinders, the scapulæ, the thigh bones, and other bones found in the northern climates, certainly belong to the elephant; it is even impossible to hesitate concerning the identity of the species. The large square teeth discovered in the same northern countries, the grinding side of which resembles the spade painted on cards, have every mark of the *dentes molares* of the hippopotamus; and those enormous teeth, the grinding side of which is composed of large blunt points or protuberances, have belonged to some terrestrial animal that now no longer exists, like the great volutes, called *cornua ammonis*, which at present exist not in the ocean.

2. The bones and tusks of these ancient elephants are every way as large as those of the Indian elephants, to which we have compared them. This is a proof that these animals did not inhabit the northern regions from any necessity, since they acquired, in that situation, their full growth and complete dimensions. Of this fact we may be ascertained by the descriptions and dimensions of them given by M. Daubenton under the article *Elephant*. But, since that time, I have had transmitted to me an entire tusk and some fragments of fossil ivory, the length and breadth of which greatly exceed the tusks of the common elephant. I searched all the shops of the Paris ivory-merchants; but I found no tusk which could be compared to that in my possession. But, of a great number, I found only one equal to those sent from Siberia, whose circumference at the base is nineteen

inches. Ivory, which is taken from living elephants; or from recent skeletons found in the forests, is denominated *raw ivory;* and the appellation of *roasted ivory* is given to that extracted from the earth, the quality of which is more or less altered, according to the time it has remained under ground, or according to the quality of the earth in which it has been buried. Most tusks which come from the north are still very solid, and very fine works may be made of them. The largest were sent to us by M. de l'Isle, an astronomer, and member of the Royal Academy of Sciences. He collected them in his travels through Siberia. In all the shops of Paris, there was not a single tusk of raw ivory which measured nineteen inches in circumference: they were all smaller. This tusk was six feet and an inch in length; and it appears, that those in the Royal Cabinet, which were found in Siberia, were, when entire, more than six feet and a half: but, as their extremities were cut off, we could only make a near guess at their real length.

If we compare the thigh bones found in the same northern countries, we shall be satisfied that they are at least equally long, and considerably thicker, than those of the Indian elephants.

Besides, as formerly remarked, we have made an exact comparison of the bones and tusks sent from Siberia with those of the skeleton of an elephant, and we found that all these bones are evidently the relics of these animals. The Siberian tusks have not only the figure, but the

genuine structure of elephant ivory, which M. Daubenton describes in the following terms:

"When an elephant's tusk is cut transversely, we see, at or near the centre, a black point, called the *heart*. But, if the tusk is cut where it is hollow, there is only a round hole in the centre. We perceive crooked lines, which extend in different directions from the centre to the circumference, and, by crossing, form small lozenges. At the circumference, there is commonly a narrow circular band. The crooked lines ramify in proportion as they recede from the centre. Hence the size of the lozenges is nearly the same throughout. Their sides, or at least their angles, are of a more lively colour then the areas, doubtless because their substance is more compact. The band at the circumference is composed of straight and transverse fibres, which, if prolonged, would terminate in the centre. It is the appearance of these lines and points which is considered as the grain of the ivory. This grain is perceptible in all ivories; but it is more or less distinct in different tusks; and, when the grain is sufficiently apparent, the ivory gets the name of *large grained*, to distinguish it from that whose grain is fine."

It cannot be supposed that elephants could be transported into Siberia by men; for the state of captivity alone, independent of the rigour of the climate, would have reduced them to a fourth or a third of the dimensions which their remains exhibit. Of this effect we have sufficient proof

from the comparison we have made between an entire skeleton of an elephant in the Royal Cabinet, which had lived sixteen years at Versailles, with the tusks of other elephants brought from their native country. This skeleton, and those tusks, though of considerable size, are one half smaller than the tusks and skeletons of those which live in freedom in Asia or in Africa; and, at the same time, they are at least two thirds smaller than the bones of the same animals found in Siberia.

3. The great quantities of ivory already discovered by accident in countries nearly desert, and where no man searches for it, show that it is neither by one nor by several accidents, nor at one and the same time, that some individuals of this species have found their way into the northern regions, but that the species had formerly existed and multiplied there, in the same manner as they now exist and multiply in southern latitudes.

The only question, therefore, which remains to be solved, is, Whether there is or has been a cause that could so change the temperature of the different parts of the globe as to render the northern regions, which are now extremely cold, equally warm as the southern climates?

Some philosophers may imagine that this effect has been produced by the change in the obliquity of the ecliptic; because, at first sight, this change seems to indicate, that, as the inclination of the axis of the globe is not permanent, the earth might formerly revolve round an axis so dif-

ferent from that on which it now turns, as to make Siberia then lie immediately under the equator. Astronomers have observed, that the change in the obliquity of the ecliptic is about forty-five seconds in a century. Hence, by supposing this augmentation to be constant and successive, sixty centuries would produce a distance of forty-five minutes, and 3,600 centuries would produce a change of forty-five degrees. Such an alteration would bring back the sixtieth degree of latitude to the fifteenth, *i.e.* the country of Siberia, where the elephants formerly existed, to the regions of India, where they still exist and multiply. Now, it may be said, we have only to admit this long lapse of time in order to account for the regular abode of elephants in Siberia: it is 360,000 years ago since the earth revolved round an axis forty-five degrees distant from that upon which it turns at present: the fifteenth degree of latitude was then the sixtieth, &c.

I answer, that this idea, and the mode of explication which results from it, cannot, upon examination, be supported. The change in the obliquity of the ecliptic is not a constant and successive diminution and augmentation. On the contrary, it is a limited variation, and sometimes on one side and sometimes on the other; and, consequently, can never produce, on any side, or in any climate, this difference of forty-five degrees of inclination; for the variation in the obliquity of the earth's axis is occasioned by the action of the planets, which alter the situation of the ecliptic, without affecting the equator. To take

the strongest of these attractions, which is that of Venus, it would require 126,000 years to make a change of 180 degrees in the ecliptic of that planet, and, of course, to produce an alteration of six degrees forty-seven minutes in the real obliquity of the earth's axis; since six degrees forty-seven minutes are the double of the inclination of the orbit of Venus. In the same manner, the action of Jupiter cannot, in 93,600 years, change the obliquity of the ecliptic above two degrees thirty-eight minutes; and still this effect is in part compensated by the preceding. Hence it is impossible that this change in the obliquity of the earth's axis should ever amount to six degrees, unless we suppose, that the orbits of all the planets should likewise change; a supposition which we cannot or ought not to admit, since no cause exists which could produce this effect.

But I am enabled to solve this difficult matter, and to deduce it from an immediate cause. We have already seen, that the terrestrial globe, when it first assumed its form, was in a state of fluidity, and that the water being unable to dissolve terrestrial bodies, this fluidity was a liquefaction occasioned by fire. Now, to pass from this burning and liquefied state to a mild and temperate heat, time was necessary. The globe could not at once cool to its present temperature. Thus, during the first ages after its formation, the heat proper to the earth was infinitely greater than that which it received from the sun; since it is still much greater. This immense fire being

afterwards gradually dissipated, the polar, like all other climates, underwent successive changes from heat to cold. Of course, a certain time, or rather a long tract of time, existed, during which the northern regions, after having burnt like all others, enjoyed the same heat which at present is felt in the southern climates. Hence these northern countries might, and actually have been inhabited by animals now peculiar to the south, and to whom this degree of heat is indispensable. The fact, therefore, instead of being extraordinary, perfectly accords with the other facts, and is no more than a consequence of them. Instead of opposing my theory of the earth, this fact, on the contrary, is an accessory proof of its reality, and confirms the most obscure point I have advanced; *i. e.* when we attempt to look back into that profundity of time, when the light of genius is apt to extinguish itself, and when, for want of observations, genius has no aid to lead us to a more remote period.

A sixth epoch, posterior to the other five, is that when the two continents were separated from each other. It is certain, that they were not separated when the elephants lived equally in the north of Europe, Asia, and America; I say, equally; for we find their bones in Siberia, in Russia, and in Canada. Hence the separation of the two continents happened posterior to the abode of these animals in the northern regions. But, as we likewise find the tusks of the elephant in Poland, in Germany, in France, and in Italy, we must conclude, that, in proportion

as these northern regions cooled, the elephants retired toward the temperate zone, where the heat of the sun, and the greater thickness of the globe, compensated the loss of the earth's internal heat; and that, in the progress of time, the temperate zone having also become too cold, the elephant gradually migrated to the climates under the torrid zone, which alone have longest preserved, by the greater thickness of the globe, a superior degree of internal heat. These are likewise the only climates where this interior heat, united with that of the sun, is still sufficient to support their existence, and to permit them to propagate their species.

Independent of the specimens transmitted from Russia and Siberia, and which are preserved in the Royal Cabinet, there are many others in private collections. Vast numbers of them are to be seen in the Musæum of Petersburgh, as appears from a catalogue printed in the year 1742. There are likewise many of them in the British Musæum, in that of Copenhagen, and in some other collections in Britain, Germany, and Italy. This northern ivory, like the southern, is used in manufacturing many articles of hardware, &c. Hence the great quantity of the tusks and bones of elephants found in Siberia and Russia can no longer remain a doubtful point.

M. Pallas, a learned naturalist, in his late journey through Siberia, found a great quantity of elephants' bones, and an entire skeleton of a

rhinoceros, which was buried a few feet only under the surface of the ground.

"Enormous bones of the elephant were lately discovered at Swijatoki, seventeen versts from Petersburgh: they were found in a spot which had long been covered with water. Hence some prodigious revolution must have changed the climate, the productions, and the animals, in every quarter of the globe. These medals of Nature prove, that those countries which are now desolated by the rigours of intense cold, have formerly enjoyed all the advantages of the southern latitudes *."

The discovery of the tusks and skeletons of elephants in Canada is but recent; and I was first informed of them by a letter from the late Mr. Collinson, fellow of the Royal Society of London, of which the following is a translation:

"Mr. George Croghan has assured me, that, in the course of his travels through the countries bordering upon the river Ohio, in the years 1765 and 1766, about four miles south-east from this river, and 640 miles distant from Fort du Quesne or Pitsburgh, he saw in the neighbourhood of a large salt marsh, where the wild animals assemble at certain seasons of the year, immense bones and teeth. Having carefully examined the place, he discovered,

* Journal de Politique et de Literature, 5 Jan. 1776, art. Petersburgh

in a high bank on the side of the marsh, a prodigious number of bones, which, from their figure and magnitude, appeared to be the bones and tusks of elephants.

"But, sir, the large grinding teeth which I send you, were found along with these tusks. There are others still larger than these, which seem to indicate, and even to demonstrate, that they belong not to elephants. How shall we reconcile this paradox? May we not suppose that there formerly existed a large animal, which had the tusks of an elephant and the grinders of the hippopotamus? for these large grinders are very different from those of the elephant. From the great number of tusks and grinders which he saw, Mr. Croghan thinks, that there must have been at least thirty of these animals buried in this place. Elephants, however, were never known in America; and it is improbable that they could be brought there from Asia. The impossibility of their living in countries where the winters are so rigorous, but where great quantities of their bones are found, makes a paradox, which your great sagacity may perhaps explain.

"Mr. Croghan, in the month of February, 1767, sent to different persons in London the bones and teeth he had collected in the years 1765 and 1766.

"1. To my lord Shelburn, two large tusks, one of which was entire, and near seven feet long: its thickness exceeded not that of a common tusk of an elephant of an equal length.

"2. A jaw bone with two grinders in it, beside several enormous separate grinders.

"To Dr. Franklin, 1. Three tusks, one of which was about six feet long. It had been broke through the middle, which was corrupted, and resembled chalk. The others were sound. The end of one of them was sharpened to a point, and it consisted of very fine ivory.

"2. A small tusk, about three feet long, and as thick as a man's arm, with the depressions made by the muscles and tendons, which were of a bright chesnut colour, and appeared to be as fresh as if recently taken from the head of the animal.

"3. Four grinders, one of the largest of which was broader than those I sent you, and had likewise an additional row of knobs. All those presented to my lord Shelburn and Dr. Franklin were of the same form, and had the sa[illegible] enamel, as the specimens I now transmit for your examination.

"Dr. Franklin lately dined with an officer, who had brought from the same place, in the neighbourhood of the river Ohio, a tusk which was whiter, more lustrous, and more entire than any of the others; and likewise a grinder still larger than any of those I have mentioned *."

* Letter from Mr. Collinson to M. de Buffon, dated Mill Hill, near London, July 3, 1767.

Extract from a Journal of a Voyage made by Mr. Croghan on the River Ohio, and transmitted to Dr. Franklin in the Month of May, 1765.

" Having passed the great river Miame, we arrived, in the evening, at the place where the bones of elephants are found. It is about 640 miles from Fort Pitt. In the morning, I went to the large marsh where the wild animals assemble at certain times of the year. We came to this place by a road beaten with the feet of the wild oxen, or bisons. It is about four miles south-east from the river Ohio. We saw a great number of bones, some of them scattered about, and others buried five or six feet below the surface. We saw them in a bank of earth along the side of the road. We found two tusks of six feet in length, which we carried to our hut, along with other bones and teeth. The following year we returned to the same place in order to procure a greater number of tusks and teeth.

" If M. de Buffon had any queries to make upon this subject, I entreated him," says Mr. Collinson, " to transmit them to me; I shall send them to Mr. Croghan, a man of integrity and parts, who will be happy to answer every question." This little memoir was subjoined to the letter which I have just now quoted, and to which I shall add an extract of what Mr. Col-

linson formerly wrote me concerning these American bones:

"About a mile and a half from the river Ohio, there are six enormous skeletons buried on end, with tusks from five to six feet long, and of the same form and substance as elephants' tusks. They were thirty inches in circumference at the root. They tapered to a point. But, as they were broken, we could not perceive how they were joined to the jaws. A thigh bone of the same animal was found entire. It weighed a hundred pounds, and was four and a half feet in length. The tusks and thigh bones show that the animal must have been of a prodigious magnitude. These facts have been confirmed by Mr. Greenwood, who saw the six skeletons in the salt marsh. In the same place, he likewise found large grinders, which appeared not to belong to the elephant, but rather to the hippopotamus. Some of these teeth he sent to London, among others, two of which together weighed 9¼ pounds. He says, that the jaw bone was too heavy to be carried by two men. The interval between the orbits of the eyes was eighteen inches. An Englishman, who had been taken prisoner by the savages, and conducted to this salt marsh in order to teach them how to make salt by evaporating the water, declared, that, from a peculiar circumstance, he remembered to have seen these enormous bones. He told, that three Frenchmen, who were breaking nuts, sat upon a single thigh bone."

Some time after writing these letters, Mr. Collinson read to the Royal Society of London two short essays on the same subject, in which I found some new facts, which I shall relate, and add elucidations of such things as may require explanation.

"The salt marsh, where the elephants' bones are found, is about four miles distant from the banks of the river Ohio, but it is more than 700 miles from the nearest coast of the sea. There is a road beaten by the wild oxen, or bisons, large enough to allow two chariots to travel abreast. This road leads directly to the great salt marsh, where these animals, as well as stags and other species of the deer, assemble at a certain season of the year to lick the earth and drink the salt water. The elephants' bones are found in a bank of about six or seven feet high, which surrounds the marsh. There we see teeth and bones, which had formerly belonged to some animals of a prodigious size. Some of the tusks are near seven feet in length, and consist of excellent ivory; and therefore we cannot entertain any doubt that they really belong to the elephant species. It is singular, however, that among all these remains, we never meet with a single grinder of an elephant; but a great number of enormous teeth, each of which has five or six blunt [illegible] [illegible] [illegible] which are flat, and [illegible] five times broader

than thick; so that these enormous grinders have no resemblance to the teeth of any known animal."

This last remark of Mr. Collinson is extremely just: these large grinders are totally different from those of the elephant; and, by comparing them with the grinders of the hippopotamus, which they resemble by their square figure, we shall perceive that they likewise differ in size, as they are two, three, and even four times more voluminous than the largest teeth of the ancient hippopotami found in Siberia and Canada, though these last teeth are three or four times larger than those of the hippopotami which now exist. All the teeth which I have examined in four heads of these animals preserved in the Royal Cabinet, have the grinding side hollowed in the form of a card spade, and those found in Canada and Siberia have the same character, and differ from them in size only. But those enormous teeth with large blunt knobs have always four and sometimes five rows; whilst the largest teeth of the hippopotamus have only three, as may be seen by comparing the figures of plate iii. iv. and v. with those of plate vi. It seems, therefore, to be certain, that these large teeth have never belonged either to the elephant or to the hippopotamus: the difference in size, though enormous, would not prevent us from regarding them as pertaining to this last species, if all the characters in their form were the same; since we know, as formerly remarked,

other square teeth three or four times larger than those of the present existing hippopotami, and which, having precisely the same characters, are unquestionably the teeth of hippopotami that have been three times larger than those whose heads are in the Royal Cabinet. I mean those large teeth, which really belong to the hippopotamus, when I remarked, that they were equally found in both continents, as well as the tusks of the elephant. It is remarkable, however, that we not only find real tusks of the elephant, and real teeth of the large hippopotamus, in Siberia and Canada, but we likewise find in the same countries those enormous teeth with four rows of large blunt knobs. We may, therefore, conclude, that this immense animal no longer exists, and that the species is entirely extinct.

M. le Compte de Vergennes, minister and secretary of state, was so obliging as to give me, in the year 1770, the largest of all these teeth, which is represented in plates iii. and iv.; it weighed eleven pounds four ounces. This immense tooth was discovered in making a ditch in Little Tartary. There were other bones which could not be collected from among these, a thigh bone, of which one part only was entire, and the cavity of the bone contained fifteen Paris pints of water. Abbé Chappe, of the Academy of Sciences, brought me from Siberia a similar tooth but smaller, and which weighed only three pounds twelve ounces and a half. (Plate v.

fig. 1 and 2.) Lastly, the largest of those transmitted to me by Mr. Collinson, and which is represented, plate vi., was found, among several others, near the river Ohio in America; and they perfectly resemble other specimens brought from Canada.

From all these facts it is apparent, that, independent of the elephant and hippopotamus, whose relics are equally found in the two continents, another animal, common to both, has formerly existed, the size of which has greatly exceeded that of the largest elephants; for the square form of these enormous grinders shows, that they were numerous in each jaw; and, supposing there were only six or even four in each side of the jaws, we may form some notion of the magnitude of a head which could contain sixteen grinders, each weighing ten or eleven pounds. The elephant has only four grinders, two on each side. They are flat, and occupy the whole jaw; and these two flat grinders of the elephant surpass by two inches only the breadth of the largest square tooth of the unknown animal, which is double the thickness of those of the elephant. Thus every circumstance leads us to think, that this ancient species, which ought to be regarded as the largest of all terrestrial animals, existed during the first ages only; for an animal much larger than the elephant could not be so concealed in any part of the earth as to remain perfectly unknown. Besides, it is evident, from the figure of these

teeth, as well as from the enamel, and the disposition of their roots, that they have no relation to the teeth of the cetaceous tribes; and that they have really belonged to a land animal, whose species made a nearer approach to that of the hippopotamus than to any other.

In the course of his essay, Mr. Collinson informs us, that several members of the Royal Society were equally well acquainted with the elephants' tusks daily found in Siberia, upon the banks of the Oby, and other rivers of that country. What system, he adds, can be formed, which will, with any degree of probability, account for those bones of the elephant found in Siberia and in America? He concludes with enumerating the weight and dimensions of all the teeth brought from the salt marsh near the river Ohio, the largest of which belonged to Captain Ourry, and weighed six pounds and a half.

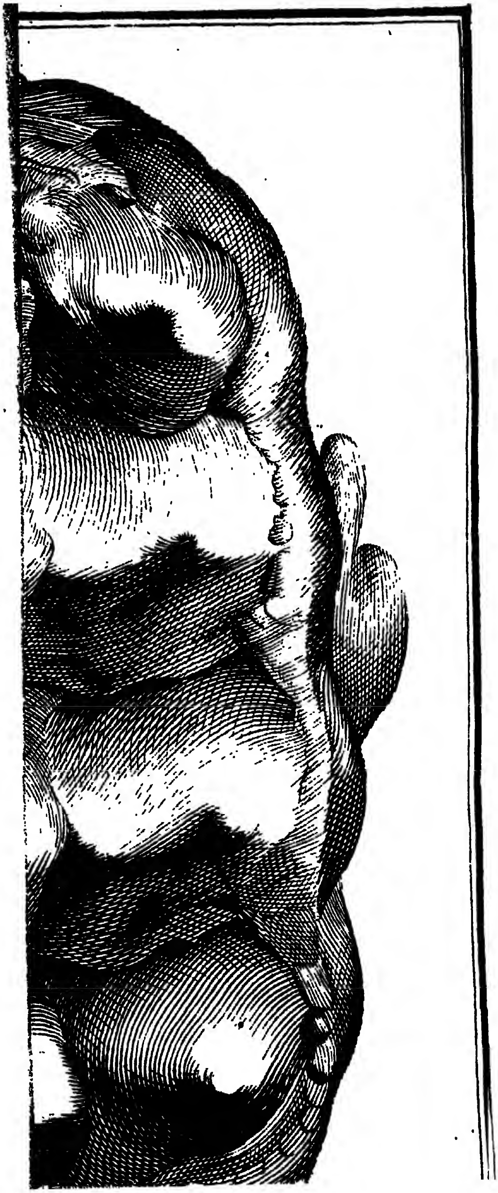
Mr. Collinson, in his second essay, read before the Royal Society of London, December 10, 1767, remarks, that, as one of the tusks found in the salt marsh was striated or furrowed near the thickest end, he entertained some doubts whether these furrows were peculiar to the elephant species. To satisfy himself on this head, he visited the warehouse of a merchant who dealt in all kinds of teeth; and, after examining them, he discovered that there were as many tusks furrowed as smooth at the thick end; and, of course, he had no difficulty in pronouncing, that the tusks

found in America were, in every respect, similar to those of the African and Asiatic elephants. But, as the large American square teeth have no relation to the grinders of the elephant, he thinks, that they are the remains of some enormous animal which had tusks like an elephant, and grinders peculiar to its own species, their magnitude and form being totally different from those of any known animal*.

In the year 1748, M. Fabri, who had made great excursions into the northern parts of Louisiana, and the southern regions of Canada, informed me, that he had seen heads and skeletons of an enormous quadruped, called by the savages, the *father of oxen;* and that the thigh bones of these animals were from five to six feet in length. Some time after, and previous to the year 1767, specimens of these large teeth, belonging to the unknown animal, as well as those of the hippopotamus, and bones of the elephant, all found in America, were transmitted to Paris. The number of them is too considerable to leave any doubt that these animals formerly existed in the northern regions of America, as well as in those of Europe and Asia.

But elephants have likewise existed in the temperate countries of our continent: I mentioned tusks found in Languedoc near Simore, and those discovered in Cominges in Gascony. To these I shall add the largest and finest of the

Plate 4



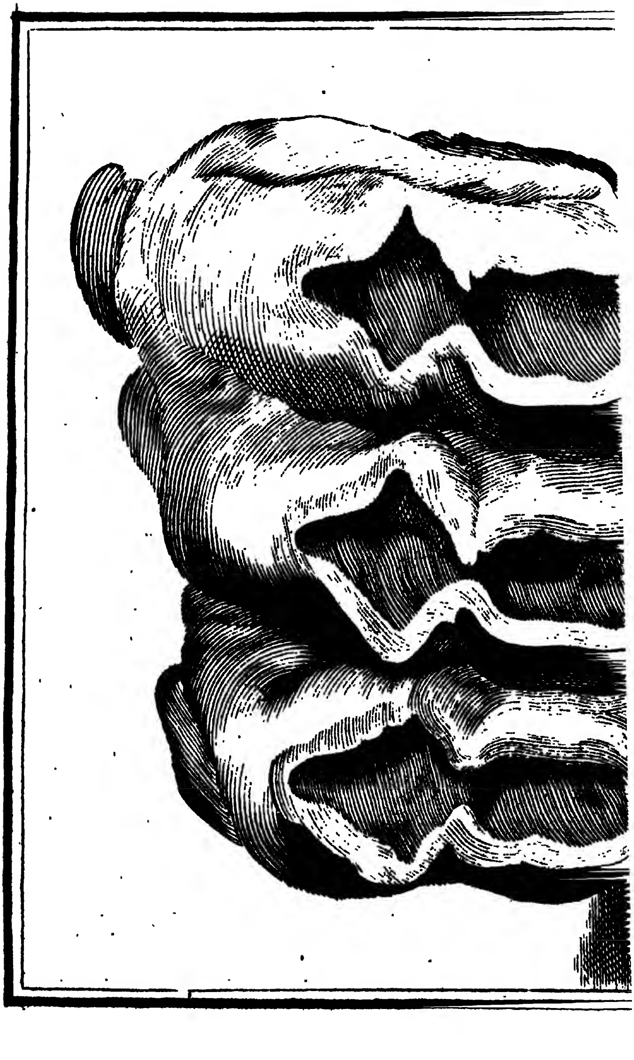


Plate 8

whole, lately sent to the Royal Cabinet by the duc de la Rochefoucauld, whose zeal for promoting science is a result of his general knowledge. This excellent specimen he found, along with M. Desmarets, of the Academy of Sciences, when viewing the fields in the environs of Rome. This tusk was divided into five fragments, which the duc de la Rochefoucauld ordered to be collected. One of these fragments was stolen by the porter who had the charge of it, and there remained only four, which were about eight inches in diameter. When laid together, these four fragments were seven feet in length; and we learn, from M. Desmarets, that the fifth fragment, which was lost, was near three feet long. Hence the total length of the tusk must have been about ten feet. By examining the broken ends, we discovered every character of elephantine ivory; though, by being long buried under ground, it has become light and friable, like all other fossil ivories.

M. Tozzetti, a learned Italian naturalist, relates, "that there were found, in the valleys of Arno, the bones of elephants and other terrestrial animals, in great quantities, scattered here and there in the strata of the earth. We may, therefore," he remarks, "conclude, that elephants were formerly natives of Europe, and especially of Tuscany *."

"We found," says M. Caliellini, "about the

* Extrait d'une Lettre du Dr. Tozzetti; Journal Etranger, mois de Decembre, 1755.

end of November, 1759, in a country estate belonging to the marquis de Petrella, situated at Fusigliano, in the territory of Cortona, a fragment of an elephant's bone mostly encrusted with a stony matter. . . . . . Similar fossil bones have formerly been discovered in our environs.

"In the cabinet of M. Galeotto Corazzi, there is another large portion of a petrified elephant's tusk, which was lately found in the neighbourhood of Cortona, at a place called La Selva. . . . . . Having compared these fragments with a piece of an elephant's tusk lately brought from Asia, we found that the resemblance between them was perfect.

"In the month of April last, M. l'Abbé Mearini brought me an entire jaw bone of an elephant, which he had found in the district of Farneta, a village belonging to this diocese. This jaw bone is mostly petrified, and particularly on the two sides, where the stony incrustation rises an inch above the surface, and has all the hardness of a stone.

"Lastly, I am indebted to M. Muzio Angelieri Alticozzi, a gentleman of this town, for a thigh bone of an elephant, which is almost entire. He discovered it in one of his country estates called Rota, which is situated in the territory of Cortona. . This bone is a Florence fathom long, and is likewise petrified, particularly in the upper extremity, called the head *."

* Lettre de M. Louis Coltellini de Cortone; Journal Etranger, mois de Juillet, 1761.

In the same manner, we find in France, and in all the other nations of Europe, skeletons and vertebræ of marine animals, which can only subsist in the most southern seas. The same change of temperature, therefore, has happened in the various parts of the ocean as well as in those of the land: and this second fact, like the first, as it proceeds from the same cause, confirms the whole.

When we compare those ancient monuments of the first age of animated Nature with her actual productions, we evidently perceive that the constituent form of each animal has remained the same, and that there is no alteration in the principal parts of their structure. The type of each species has suffered no change. The internal mould has invariably preserved its form. However long we may suppose the succession of time, whatever number of generations may have passed, the individuals of each kind still exhibit the same forms as those of the first ages, especially in the larger species, whose characters are more fixed, and whose nature is more permanent; for the inferior species have, as formerly remarked, been sensibly affected by the different causes of degeneration. We must, however, remark, with regard to the larger species, such as the elephant and hippopotamus, that, by comparing their ancient remains with those of our times, we, in general, perceive that these animals were then much larger than they are at present. Nature was then in her primitive vigour. The internal heat of the earth bestowed

on its productions all the vigour and magnitude of which they were susceptible. The first ages produced giants of every kind. Dwarfs and pigmies succeeded, after the earth had cooled; and if, as other monuments seem to indicate, some species of animals, which formerly existed, are now lost, this effect could only be produced, because their nature required a greater degree of heat than what is now felt in the torrid zone. Those enormous and nearly square grinders with blunt knobs, those large cornua ammonis, of which some are several feet in diameter, and many other fossil fishes and shells, which no longer have any living representatives, existed only in those primitive times when the earth and sea were still warm, and produced and nourished animals to whom this degree of heat was necessary, and who exist not at present, because they have probably perished by cold.

To know all the petrifactions of which there are no living representatives, would require long study and an exact comparison of the various species of petrified bodies, which have been found in the bowels of the earth. This science is still in its infancy. We are certain, however, that there are many of those species, such as the cornua ammonis, ortoceratites, lenticular and numismal stones, belemnites, Judaic stones, anthropomorphites, &c., which cannot be referred to any species now existing. We have seen cornua ammonis of two and three feet in diameter; and we have been assured, by men worthy of credit, that a cornua ammonis has been found in Cham-

pagne larger than a mill-stone, since it was eight feet in diameter and one foot thick. I had an offer of its being sent to me. But the enormous weight of this mass, which is 8,000 pounds, and its great distance from Paris, prevented me from accepting the present. These examples, and others which might be given, are sufficient to show, that many species of shell and crustaceous animals formerly existed in the sea, of which there are now no living representatives. The same observation is applicable to some of the scaly fishes. Most of those found in certain slates have so little resemblance to the fishes with which we are acquainted, that their species cannot be ascertained. Even those in the Royal Cabinet, which are perfectly preserved in masses of stone, cannot be referred to any of our known species. It appears, therefore, that the sea formerly nourished many genera, whose species no longer exist.

But, with regard to terrestrial animals, we have only a single example of a lost species, and it appears to have been the largest, without excepting even the elephant: and, since the examples of lost species are more rare in land than in marine animals, is it not probable that the production of the former was posterior to that of the latter?

From these facts and monuments we may perceive six successive epochs in the first ages of Nature; six species of duration, the limits of which, though indeterminate, are not the less real; for these epochs are not like those of

civil history, marked by fixed points, or limited by centuries and other portions of time, which admit of an exact measurement. They may, however, be compared between themselves, and their relative duration may be estimated by other facts and monuments, which indicate contemporary dates.

* * * * * *

After finishing his preliminary discourse, the count de Buffon proceeds to state the different epochs of Nature, which he divides into seven great periods.

EPOCH FIRST.

When the earth and planets first assumed their proper form.

EPOCH SECOND.

When the fluid matter consolidated and formed the interior rock of the globe, as well as those great vitrifiable masses which appear on its surface.

EPOCH THIRD.

When the waters covered all the continents.

EPOCH FOURTH.

When the waters retired, and volcanos began to act.

EPOCH FIFTH.

When the elephants, and other animals of the south, inhabited the northern regions.

EPOCH SIXTH.

When the continents were separated from each other.

EPOCH SEVENTH, and last.

When the power of man assisted the operations of nature.

These epochs are purely hypothetical, and depend more or less on the notion, that the earth and planets were originally driven from the body of the sun by the impulse of a comet, and, of course, remained long in a state of liquid fire. We shall therefore content ourselves

with having barely mentioned them; and proceed to enumerate some facts and positions, which, though applied in support of a fanciful system, are curious, and may be useful.

The count de Buffon remarks, that the cavities and eminences of the globe have been encrusted, and sometimes filled with metallic substances, which are still found in these situations.

"Metallic veins," says M. Eller, "are found only in elevated places, in a long chain of mountains. This chain of mountains is always supported by a basis of hard rock. As long as this rock preserves its continuity, there is no chance of discovering metallic veins. But, when we meet with crevices or fissures, we then entertain hopes of finding metal. Mineralogists have remarked, that, in Germany, the most favourable situation is when the mountains rise gradually, stretch toward the south-east, and, after attaining their greatest elevation, descend gently toward the north-west. . . . .

"It is generally in a rugged rock, the extent of which is often unlimited, but split into fissures, that metals are found sometimes pure, but generally in the state of ores. These fissures are commonly encrusted with a white shining substance, called *quartz* by the miners: when heavier, but soft and laminated, nearly like chalk, it receives the denomination of *spar*. It is surrounded, on the side next the rock, with a kind of slime, which seems to nourish these quartzy or sparry earths. These two coverings serve as a sheath for the vein. The more perpendicular

the vein, the more is to be expected from it. Whenever the miners find a perpendicular vein, they say that it will be very productive.

" In these fissures and cavities, metals are formed by a perpetual and pretty strong evaporation. The vapours which issue from mines show that this evaporation is still going on. Fissures which have no exhalation are commonly barren of metal. The most certain proof that the exhaling vapours carry along with them mineral particles, and apply them to the sides of the fissures, is that successive encrustation, which is apparent in the whole circumference of these fissures or hollows of rocks, till their cavities are completely filled, and the solid vein is formed. This fact is still farther confirmed by the tools left in these hollows; and, several years after, they are found to be encrusted with metal.

" The fissures which furnish the richest veins of metal always incline to a perpendicular direction. In proportion as the miners descend, the temperature of the air is always warmer; and the exhalations are sometimes so abundant and so noxious, that, in order to avoid suffocation, the miners are obliged to fly to the pits or galleries, otherwise they would be instantly destroyed by the arsenical and sulphureous particles. Sulphur and arsenic are commonly found in the four imperfect, and in all the semimetals, and it is from these they receive their metallic form.

" Gold, and sometimes silver and copper, are

the only metals which are found pure in any quantities. But, in general, copper, iron, lead, and tin, when taken out of the veins, are mineralized with sulphur and arsenic. We know, from experience, that metals lose their metallic form by degrees of heat proportioned to each species. This destruction of the metallic form, which the four imperfect metals undergo, shows that the basis of metals is an earthy matter; and, as these calces, as well as the calcarious and gypseous earths, vitrify by the application of a certain degree of heat, we are certain that metallic earth belongs to the class of vitrifiable earths *."

M. Lehman, a celebrated chemist, is the first person who suspected that metallic substances had a double origin. "Gold and silver," he remarks, "are found in masses only in the mountains which have veins, and iron is found only in those mountains which have regular strata. All the small pieces of gold and silver found in the mountains with strata have been detached from veins in the superior mountains in the neighbourhood of the former.

"Gold is never in the form of ore. It is always found in a native or virgin state, though it is often scattered about in particles so minute, that it cannot be distinguished even by the best microscopes. In the mountains with strata, no gold, and very little silver, are to be found. These

* Mem. de M. Eller sur l'Origine et la Generation des Metaux.

two metals belong exclusively to mountains with veins. Sometimes, however, we find silver in small leaves, or under the form of hair, in slate. Native copper oftener occurs in slate; and this copper is also commonly in the form of threads or hair.

" A few years after iron ores have been taken from the earth, they are reproduced. They are not found in the mountains with veins, but in those with strata. Iron is seldom, if ever, met with in a native state.

" With regard to native tin, it has no existence in nature, and is only produced by the assistance of fire. The same remark is applicable to lead, though the grains found in Silesia have been considered as native lead.

" Native mercury is found in strata of fat argillaceous earth, or in slate.

" The silver ores found in slate are not nearly so rich as those found in the mountains with veins. This metal is found in beds of slate; and is always in the form of minute particles, threads, or ramifications, but never appears in large masses. These beds of slate must likewise be adjacent to the mountains with veins. The silver ores found in strata are never in a solid or compact form. All the other ores, which contain much silver, are peculiar to the mountains with veins. There is a great deal of silver in the strata of slate; and it is also sometimes found in pit-coal.

" Tin is the metal which most rarely appears in strata; lead is more common in that situa-

tion. We find it attached to slate, but never to coal.

" Iron is almost universally diffused, and is found in beds under a number of different forms.

" Cinnabar, cobalt, bismuth, and lapis calaminaris, are likewise commonly found in beds.

" Pit-coal, jet, amber, and aluminous earth, are produced by vegetables, and especially by resinous trees which have been buried in the earth, and have been more or less decomposed; for we often find, above the strata of coal, wood which is not totally decomposed; and it is still more decomposed as we descend deeper. Slate, which covers coal, is often full of the impressions of plants, such as ferns, maiden-hair, &c. It is remarkable, that all these impressions belong to foreign plants, and the wood likewise appears to be foreign. Amber, which ought to be regarded as a vegetable resin, often includes insects, which, when attentively examined, belong not to the climate where they now exist. Aluminous earth is frequently laminated, and resembles wood sometimes more and sometimes less decomposed.

" Sulphur, alum, and sal ammoniac, are found in beds formed by volcanos.

" Petroleum and naphtha indicate a subterraneous fire, which produces a distillation from pit-coal. We have examples of these subterraneous fires which act silently, in the coal strata of Britain and Germany. They burn long without any explosion; and it is in the neighbourhood of these subterraneous fires that hot springs are found.

"The mountains which contain veins include neither coal nor bituminous and combustible bodies: these substances are found only in the mountains with strata."

In the second epoch of Nature, the count de Buffon remarks, "that, in the northern regions there are mountains composed entirely of iron." I mention, says he, by way of example, the iron mines near Taberg in Smoland, a part of the island of Gothland in Sweden. It is the most remarkable of those mines, or rather mountains of iron, which have the quality of yielding to the attraction of the loadstone; which proves that they have been formed by the action of fire. The basis of this mountain is a very fine sand. Its height is more than 400 feet, and its circumference about one league. It is composed entirely of a rich ferruginous matter, and we even find in it native iron, which is another proof that it has undergone the action of a violent fire. This ore, when broken, exhibits small shining particles, which sometimes cross each other, and sometimes are arranged like scales. This mine has been wrought above 200 years.

The ore in this mountain is not disposed in regular beds; neither is the iron every where of equal goodness. Through the whole mountain there are fissures sometimes perpendicular and sometimes horizontal: these are all filled with sand, which contains no iron. This sand is pure, and of the same species with that on the sea-coast. In this sand, we sometimes find the bones of animals, and the horns of stags, which

shows that the sand has been carried thither by the waters, and that the formation of this iron mountain by fire happened before the crevices and the perpendicular and horizontal fissures were filled with sand.

The masses of ore are rolled down from the top of the mountain; but, in other mines, the minerals must be drawn up from the bowels of the earth. This ore must be broken to pieces, or pounded, before it is put into the furnace, where it is smelted by means of charcoal and calcarious stones.

This hill of iron is situated in an elevated and mountainous district, about eighty leagues from the sea: it seems to have formerly been altogether covered with sand *.

We are next informed, that there are mountains of loadstone in some countries, and particularly in those of the north. From the foregoing example, we have seen that the iron mountain of Tabèrg rises 400 feet above the level of the sea. M. Gmelin, in his travels through Siberia, remarks, that, in the northern countries of Asia, almost all the metallic ores are found on the surface of the earth, whilst in other countries they are buried deep in the interior parts. This fact, if generally true, is a new proof that metals have been formed by the primitive fire, and that the globe, being less thick in

* Extrait d'un Article de l'Ouvrage periodique qui a pour titre, *Norsdilche beytrage*, &c. Contribution du Nord pour les Progrés de la Physique, de Sciences, et des Arts, 1756.

the northern regions, metals were formed nearer the surface than in the southern countries.

M. Gmelin examined the great mountain of loadstone among the Baschkires in Siberia. This mountain is divided into eight parts by valleys, of which the seventh part produces the best loadstone. The summit of this portion of the mountain consists of a yellowish stone, which seems to partake of the nature of jasper. We there find stones that have the appearance of free-stone, which weigh from 2,000 to 3,000 pounds; but they all have a magnetic virtue. Though covered with moss, they fail not, at more than the distance of an inch, to attract iron and steel. The sides exposed to the air have the strongest magnetic power, those covered with the earth being much weaker. Those parts which are exposed to the injuries of the air are softer, and, consequently, less proper for being armed. A large portion of loadstone, of the size above mentioned, is composed of a number of other portions, which act in different directions. To work them properly, they should be separated in such a manner that the whole portion, which includes the virtue of each particular magnet, should preserve its unity: by observing this rule, we would probably obtain magnets of an uncommon strength. But, as they are cut without any foresight, many portions are of no value, either because they contain little or no magnetic power, or because, in a single piece, there are two or three magnets

united; such portions have indeed a magnetic virtue; but, as it is not directed to the same point, a magnet of this kind must be subject to great variations.

The loadstone of this mountain, except what is exposed to the air, is exceedingly hard, spotted with black, and full of little knots or protuberances, consisting of small angular parts, like those often observable on the surface of bloodstone, from which it differs only in colour; but, instead of these angular parts, we sometimes perceive a kind of ochery earth. In general, loadstones with these angular parts have less power than the other kinds. That part of the mountain where the loadstones are found is composed almost entirely of a fine iron ore, which lies in small portions among the loadstones. The whole section of the high part of the mountain contains a similar ore; but, in proportion as we descend, the metal is more rare. Below the ore of loadstone, there are other ferruginous stones, which, if melted, would produce very little iron. These stones have the colour of metal, and are very heavy. Their interior parts are irregular, and have nearly the appearance of scoriæ. In their surfaces they pretty much resemble loadstones; but they have no magnetic power. Between these stones there are other pieces of rock which appear to be composed of small particles of iron. The stone itself is heavy, but very soft. The interior parts resemble burned matter, and they have little or no magnetic vir-

tue. We likewise meet occasionally with a brown iron ore in beds of an inch thick; but it yields very little metal*.

In the mountains of Poias, in Siberia, there are several other mines of loadstone. Ten leagues off the road which leads from Catharinbourg to Salikamskaia, there is a hill called Galazinski, which is more than twenty fathoms high, and is entirely composed of a loadstone rock. It has the brown colour and the density of iron.

Twenty leagues from Salikamskaia, we find cubical loadstones of a brilliant greenish colour. When pulverised, the grains have the appearance of fire. It is worthy of remark, that loadstone is found only in those chains of mountains which stretch from south to north†.

In the countries bordering upon Lapland, and on the confines of Bothnia, two leagues distant from Cokluanda, there is an iron ore, from which very fine loadstones are extracted. "We admired," says Regnard, "the surprising effects of this stone, when it remained in its natural situation. It required a great deal of force to obtain pieces of the magnitude we wished; and the large hammer employed remained so fixed to the wedge in the stone, that the workman required assistance to disengage it. I tried the

* Extrait d'Hist. Generale des Voyages, tom. xviii. p. 141, &c.

† Ibid. tom. xix. p. 472.

experiment myself; I took a large iron lever, which was so heavy that I could hardly support it; I brought it near the wedge, by which it was attracted and supported with an amazing force. I held a mariner's compass in the middle of the hole where the ore lay, and the needle revolved perpetually with an incredible rapidity*.

In vol. i. p. 30, I remarked, "that, according to the relation of voyagers, the mountains of the north are but small hills when compared to the mountains of the equatorial regions; and that the general movement of the waters produced those large mountains in the Old Continent, which stretch from east to west, and from north to south in the New."

This passage requires explanation, as well as some restrictions. From a thousand observations, it is certain, that shells and other productions of the ocean, are found upon the whole surface of the inhabited parts of the earth, and even upon the mountains to a very great height. I advanced, from the authority of Woodward, who first collected facts upon this subject, that shells were likewise found upon the tops of the highest mountains. From my own observations, as well as those of others, I know, that there are shells in the Alps and Pyrennees at 900, 1,000, 1,200, and 1,500 fathoms above the level of the sea; that they are likewise found in the

* Oeuvres de Regnard, tom. i. p. 185.

mountains of Asia; and, lastly, in the Cordeliers of America, a bank of shells has lately been discovered at the height of more than 2,000 fathoms above the sea *.

It is, therefore, certain, that, in all the different parts of the world, and even to the height of 1,500 or 2,000 fathoms above the present level of the sea, the surface of the globe has been covered with the waters, and that they remained long enough for the production and multiplication of shell animals; for the quantity of them is so great, that their spoils often form large banks, which extend many miles in length. They compose a considerable part of the exterior strata of the earth; for calcarious substances, or the spoils of shells, are very common in most

* M. le Gentil, of the Academy of Sciences, wrote me the following letter, in December, 1771: "Don Antonio Ulloa desired me, when departing from Cadiz, to send him two petrified shells, which, in the year 1761, he had dug out of the mountain that contains the quicksilver mines. This mountain is in the government of Ouanca-Velica in Peru. Its southern latitude is from 13 to 14 degrees. At the place where these shells are found, the mercury stood at 17 inches $1\frac{1}{4}$ line, which corresponds to the height of $2,222\frac{1}{3}$ fathoms above the level of the sea.

"At the top of the mountain, which is far from being the highest in this canton, the mercury stands at $16\frac{1}{2}$ inches, which implies a height of $2,337\frac{2}{3}$ fathoms.

"In the town of Ouanca-Velica, the mercury stands at 18 inches $1\frac{1}{2}$ line, which gives a height of 1,949 fathoms.

"Don Antonio Ulloa informed me, that he detached these shells from a very thick bank, the extent of which he did not know: the shells are of the large pilgrim or scallop kind."

countries. But, at high points of elevation, *i. e.* above 1,500 or 2,000 fathoms, the summits of the mountains generally consist of pure rock, granite, and other vitrifiable bodies, produced by the primitive fire, which contain no shells, madrepores, or any thing that has a relation to calcarious substances. We may, therefore, conclude, that the sea has never reached, or at least for a short time only, those most elevated parts of the earth.

To support the testimony of Don Ulloa, concerning the shells found in the Cordeliers, we shall add that of Alphonso Barba. He tells us, that, in the most mountainous parts of Peru, there are shells of all sizes, some of them concave, others convex, and the whole finely impressed*. Hence America, as well as the other quarters of the globe, has been covered with the waters of the sea. The first observers were probably induced to think that no shells were to be found in the Cordeliers, because most of these mountains, which are the highest on this globe, are either active or extinguished volcanos, the eruptions of which have covered all the adjacent countries with burned substances: of course, all the shells which might have been found there, are not only buried, but completely destroyed. It is not, therefore, surprising that no marine productions have been discovered around these mountains, which either are at present, or have formerly been volcanos; for the territories

* Metallurgie d'Alphonso Barba, tom. i. p. 64.

which surround these mountains must be composed entirely of ashes, scoriæ, glass, lava, and other burned or vitrified bodies. Thus the notion that the sea never covered the mountains, has no other foundation than this circumstance, that, on the tops of several of them, no shells or other productions of the sea are now to be seen. But, as we find, in an infinite number of places, and even as high as 1,500 or 2,000 fathoms, shells and other sea bodies, it is evident, that there are few ridges of mountains which have not been covered with the ocean; and that the spots where no shells appear only show that the animals which produce them have never dwelt there, or that the motion of the waters has not transported thither marine productions, as it has done in every other part of the globe.

We are next informed, that some fishes and plants can live and vegetate in waters so hot as from fifty to sixty-three degrees of the thermometer. There are many examples of plants growing in the hottest bath waters; and M. Sonnerat found fishes in water the heat of which was so great that he durst not plunge his hand into it. "Two leagues from Calamba," says he, "I found, in the isle of Luçon, near the village of Bally, a brook, the water of which was so hot that Reaumur's thermometer, when plunged into it, about a league from its source, stood at the sixty-ninth degree. Upon perceiving such a degree of heat, I imagined, that all the productions of Nature must have been extinguished upon the margin of this brook. But I was much surprised when I

saw three vigorous shrubs, the roots of which were immersed in this boiling water, and their branches surrounded with its vapour. The heat was so great, that, when the swallows attempted to cross the water at seven or eight feet high, they uniformly fell down dead. One of these shrubs was an agnus castus, the other two were a species of broom called aspalathus. During my abode in this village, I constantly drank this water after it was cooled. Its taste seemed to be earthy and ferruginous. Several baths are constructed along this brook, and their degrees of heat are proportioned to their distance from its source. When I visited the first bath, my surprise was increased: in this water, which was so hot that I durst not plunge my hand into it, I saw fishes swimming. I used every effort to procure some of them; but their agility, and the want of address in the people, prevented me from succeeding. I examined them in the water; but I could not distinguish their genus, on account of the vapour rising from the water. They had brown scales, and the largest of them were about four inches long. I could not learn how these fishes had got into the baths." The testimony of M. Sonnerat is strengthened by that of M. Prevost, who travelled with him into the interior parts of the isle of Luçon. "You was right," M. Prevost remarks, "to communicate to M. de Buffon the observations you collected when we travelled together. You desired me to confirm in writing what surprised us so much in

the village of Bally, situated on the margin of the Laguna of Manilla, at Los-bagnos. I am sorry I have not a copy of our observations made with Reaumur's thermometer. But I clearly recollect, that the water of the small brook, which passed through this village to fall into the lake, made the mercury rise to sixty-six or sixty-seven degrees, though it was plunged into the water at a league's distance from the source of the brook. The margins of this brook were covered with a very fine green carpet. You cannot have forgot the agnus castus we saw in flower, the roots of which were moistened with the water of the brook, and its stem and branches perpetually surrounded with its steams. The curate of the village likewise assured me, that he had seen fishes in this same brook. This fact I cannot certify. But I saw fishes in one of the baths, the heat of which raised the mercury to forty-eight and fifty degrees*."

I know not whether fishes have ever been found in our hot waters: but it is certain that the bottom of the hottest of them is covered with plants. M. l'Abbé Mazéas informs us, that, in the almost boiling water in the Solfatara of Viterbe, the bottom of the basin is covered with the same plants which grow at the bottoms of lakes and ditches †.

* Voyage à la Nouvelle Guineé par M. Sonnerat, Correspondent de l'Academie Royale des Sciences, èt du Cabinet Roi, p. 38, &c.

† Mem. des Savans Etrangers, tom. v. p. 325.

Of Giants.

From monuments which still remain, it appears, that gigantic animals of different kinds have formerly existed.

The large teeth with blunt knobs which I formerly described, indicate the existence of an animal whose magnitude greatly surpassed that of the elephant. But this gigantic species is now entirely annihilated. Other large teeth, the grinding face of which resembles spades on cards, like those of the hippopotamus, and which are four times larger than the teeth of the present hippopotamus, show that there has been a very gigantic species of this animal. The enormous thigh bones, which far exceed the dimensions of those of our elephants, demonstrate the same thing with regard to the elephant species.

In the year 1772, there was found, near Rome, a petrified head of an ox, which P. Jacquier describes in the following manner: "The length of the front, between the two horns, is two feet three inches; the distance between the orbits of the eyes, fourteen inches, and that from the superior part of the front to the orbit of the eye one foot six inches; the circumference of the horn at the base, is one foot six inches; the length of the horn four feet; and the distance between the ends of the horns three feet. The internal part of this petrifaction

is extremely hard. This head was found at Puzzolani more than twenty feet below the surface of the ground *.

"In the year 1768, I saw, in the cathedral of Strasburg, a large horn of an ox suspended by a chain to a pillar near the choir. It appeared to be three times bigger than those of our largest oxen. As it was hung very high, I could not take the exact dimensions, but I judged it to be about 4½ feet long, and from seven to eight inches in diameter at the base †."

Lionel Waffer relates, that he saw, in Mexico, bones and teeth of a prodigious size: among others, he saw a tooth three inches broad, and four in length. Having consulted the most intelligent people of the country, they concluded that the head could not be less than a yard broad ‡.

It is, perhaps, the same head which Acosta mentions: "I saw," says he, "a grinder which astonished me by its enormous size; for it was as large as a man's fist." P. Torquemado, a Franciscan, relates, that he had in his possession a grinder, twice as large as a man's fist, and which weighed two pounds. He adds, that, in the city of Mexico, and in the Convent of St. Augustine, he saw a thigh bone so large, that the

* Gazette de France du 25 Septembre, 1772, art. de Rome.

† Note communicated to M. de Buffon by M. Greignon, Sept. 24, 1777.

‡ Waffer's Travels in America, p. 267.

individual to which it belonged must have been from eleven to twelve cubits high, *i. e* seventeen or eighteen feet; and that the head must have been as big as one of the large pitchers used in Castille for holding wine.

Phillippe Hernandés informs us, that there were found, at Tezaco and Tosuca, several bones of an extraordinary magnitude; and that among these there are grinding teeth five inches broad and ten high; from which he concludes, that the size of the head must have been so enormous that two men could not have embraced it with their arms. Don Lorenzo Boturini Benaduci likewise tells us, that, in New Spain, and particularly in the heights of Santafé, and in the territories of Puebla and Ttlascala, they find enormous bones and grinders, one of which, preserved in the Royal Cabinet, is a hundred times larger than the largest human teeth *.

The author of this Gigantologie Espagnole attributes these enormous teeth and bones to giants of the human species. But, is it credible that men ever existed whose heads were eight or ten feet in circumference? Is it not equally astonishing, that, in the species of the hippopotamus or elephant, there have been individuals of this magnitude? We are, therefore, led to think, that these enormous teeth are of the same kind with those lately found in Canada near the river Ohio, which we ascribed to an unknown

* Gigantologie Espagnole, par le P. Torrubia, Journal Etranger, Nov. 1760.

animal, whose species formerly existed in Tartary, in Siberia, and in Canada, and which extended from the Illionois as far as Mexico. As the Spanish authors do not mention that elephants' tusks were found in New Spain along with these large grinders, it is probable that a species different from that of the elephant formerly existed there, to which these large grinders belonged, and that this species was diffused as far as Mexico. Besides, the large teeth of the hippopotamus seem to have been anciently known; for St. Augustine tells us, that he saw a grinder so large, that, if divided, it would have made 100 teeth of an ordinary man *. Fulgosa likewise remarks, that teeth were found in Sicily, each of which weighed three pounds †.

John Sommer relates, that he found, near Chatham in Canterbury, at the depth of seventeen feet below the surface of the earth, monstrous bones, some of them entire, and others broken. He likewise found four entire teeth, each of them weighing more than half a pound, and nearly as large as a man's fist. The whole four were grinders, and, except in magnitude, they pretty much resembled human teeth. He farther remarks, that Louis Vives mentions a grinder still larger, which was shown him for a tooth of St. Christopher. He adds, that Acosta saw in India a similar tooth dug out of the earth, along with several other bones, which, when ar-

* De Civitate Dei, lib. xv. cap. 9.

† Ibid. lib. i. cap. 6.

ranged in proper order, represented a man of a monstrous stature. "We might have formed the same idea," says Mr. Sommer, "concerning the teeth dug out of the earth near Canterbury, if bones had not been found in the same place, which did not belong to the human species." Several persons who examined these bones, judged them to be the bones and teeth of the hippopotamus. Two of these teeth are engraved in the Philosophical Transactions, num. 272, fig. 9.

From these facts we may conclude, that most of those large bones found under the surface of the earth belong to the elephant and hippopotamus: but it seems to be certain, that, by comparing the enormous teeth with blunt knobs with those of the elephant and hippopotamus, they have belonged to an animal much larger than either, and that the species of this prodigious animal no longer exists.

Among the present elephants, it is extremely rare to find a tusk of six feet in length. The longest are generally from five to six and a half feet; and, of course, the ancient elephant, which produced a tusk of ten feet long, whose fragments are in our possession, was a gigantic species. The immense thigh bone in the Royal Cabinet confirms the same conclusion.

The same remark is applicable to the species of the hippopotamus. I caused two of the largest grinders to be extracted from the largest head of the hippopotamus in the Royal Cabinet: one of them weighed ten, and the other nine and a half ounces. I then weighed two teeth, the one found

in Siberia, and the other in Canada. The first weighed two pounds twelve ounces, and the second two pounds two ounces. Hence these ancient hippopotami were gigantic when compared with those now existing.

The example already given of the enormous petrified head of an ox, found in the environs of Rome, proves, that there have likewise been prodigious giants in this species of quadruped, which we are also enabled to show by several other monuments of antiquity. In the Royal Cabinet, we have, 1. A fine, greenish horn, which is very smooth and well turned, and evidently belongs to the ox. The circumference at the base is twenty-five, and its length forty-two inches. Its cavity contains eleven and a quarter Paris pints of liquor. 2. The core, or internal bone of an ox's horn, which weighs seven pounds; whilst the largest core of the horns of our oxen exceeds not the weight of one pound: this internal bone was presented to the Royal Cabinet by M. le Comte de Tressan, a man of taste, and a good natural historian. 3. Two internal bones of an ox's horn, attached to a portion of the cranium, were found in beds of turf, at the depth of twenty-five feet, between Amiens and Abbeville, and transmitted to me for the Royal Cabinet. The whole weighed seventeen pounds; and each horn bone, when separated from the cranium, weighed at least seven and a half pounds. I compared the dimensions, as well as the weight of these different bones; that of the largest ox to be found in Paris was only thirteen inches long, and seven in circum-

ference at the base. But, of the two dug out of the earth, the one was twenty-four inches long, and twelve in circumference at the base, and the other twenty-seven inches in length, and thirteen in circumference. These facts* are more than sufficient to show, that, in the species of the ox, as well as in those of the hippopotamus and elephant, prodigious giants have formerly existed.

With regard to the human species, individual giants have been produced not only in Asia, but in every climate; for, even in our own days, we see gigantic men in every country. We lately saw a giant who was born in Finland, on the very confines of Lapland. But we are not equally certain, that permanent races, and far less entire nations of giants, ever existed. However, the testimony of ancient authors, and especially those of Holy Writ, seem clearly to indicate, that races of giants formerly existed in Asia. In the book of Numbers, chap. xiii. verse 33, it is said, *And there we saw giants, the sons of Anak, which came of the giants: and we were in our own sight as grasshoppers, and so we were in their sight.* Though this description may have the appearance of exaggeration, which is common in the oriental style, it is plain that these giants were very large.

In 2 Samuel, chap. xxi. verse 20, a giant is mentioned of the race and family of Goliah, who had six fingers and toes on his hands and feet: in the same book there are several other passages which prove the existence and destruction of giants.

In Joshua, chap. ii. verse 22, it is said, that *there was none of* the giants of the race *of the Anakims left in the land of the children of Israel; only in Gaza, in Gath, and in Ashdod, there remained.*

Philo, St. Cyrillus, and several other authors, seem to think, that the word *giants* means only proud and impious men, and not men of an extraordinary stature. But there is no foundation for this opinion; since the amazing height and strength of these men are often described.

The prophet Amos informs us, that the Lord *destroyed the Amorite, whose height was like the height of cedars, and he was strong as the oaks.*

Ogg, king of Basan, was nine cubits high, and Goliah ten cubits and one palm. Ogg's bed was nine cubits, or thirteen and a half feet long, and four cubits, or six feet, broad. The breastplate of Goliah weighed two hundred and eight pounds four ounces, and the blade of his lance twenty-five pounds.

These evidences are sufficient to prove, that there formerly existed, in the continent of Asia, not only individuals, but races of giants, who have been destroyed, and the last of whom appeared in the days of king David. Nature, who never loses any of her rights, sometimes resumes her former powers of production; for, in almost every climate, men of an extraordinary stature, *i. e.* of seven and a half, eight, and even nine feet high, occasionally appear. Beside the examples already given, many others are to be found, both

in ancient and modern authors, of giants of ten, twelve, fifteen, and eighteen feet high. But these last dimensions, I am persuaded, ought to be greatly reduced. The bones of elephants have often been mistaken for human bones. Besides, Nature, in her present appearance, presents no species with such great disproportions, except, perhaps, that of the hippopotamus; for the teeth of those found in the bowels of the earth are at least four times larger than the teeth of the hippopotamus which now exists.

The bones of the supposed king Teutobochus, found in Dauphiny, gave rise to a dispute between Habicot, a surgeon in Paris, and Riolan, the famous anatomist. Habicot, in his *Gigantosteologie*, tells us, that these bones were taken out of a brick sepulchre, eighteen feet below ground, and surrounded with sand. He neither gives an exact description, nor the number of these bones. He asserts that they are human, because they belonged to no other animal. He adds, that some masons, when working for Seignior Langon, a gentleman of Dauphiny, on the 11th day of January, 1613, discovered this tomb near the ruins of the castle of Chaumont; that the tomb was built with brick; that it was thirty feet long, twelve broad, and eight high; that it was covered with a gray stone, on the middle of which was engraved, *Teutobochus Rex*; that, when the tomb was opened, a human skeleton appeared, which was 25½ feet long, ten broad at the shoulders, and five thick; that, before touching these

bones, the head was measured, and it was five feet in length, and ten in circumference. Here it is worthy of remark, that the proportion between the length of a human head and that of the body, is not a fifth, but a seventh and one half; so that this head of five feet supposes the body to have been 37½ feet in length. Lastly, Habicot tells us, that the under jaw was six feet round, and the orbits of the eyes seven inches: that each clavicle was seven feet long; and that most of these bones, after being exposed to the air, crumbled into dust.

In the same year, 1613, Dr. Riolan published a tract under the title of *Gigantomachie,* in which he maintains, that Habicot, in his Gigantosteologie, had given false measures of the body and bones of the pretended giant Teutobochus; that Riolan measured the thigh bone and the bone of the leg together with the astragalus joined to the calcaneum; that they exceeded not 6½ feet, even including the os pubis; and, of course, that the length of the giant could be only thirteen feet, instead of twenty-five. He then gives his reasons for denying these bones to be human; and concludes, that the bones exhibited by Habicot belong not to man, but to the elephant.

A year after the publication of Habicot's Gigantosteologie and Riolan's Gigantomachie*, a pamphlet appeared under the title of *The Imposture, concerning supposed human Bones falsely attributed to King Teutobochus, discovered.* In this pamphlet, the bones are denied to be human, and

supposed to have been engendered by some virtue in the earth. Another pamphlet was published without a name, in which it is said, that, among these bones, some were human and others not.

In 1618, Riolan published his Gigantologie, in which he maintains, that the bones in question were not only not human, but that men in general were never larger than they are at present.

In the same year, Habicot replied to Riolan: he says, that he presented his Gigantosteologie to Louis XIII.; that, about the end of July, in the year 1613, the bones mentioned in this work were exposed to the eye of the public; and that they are real human bones. He quotes a number of examples from ancient and modern authors, to prove that men of immense stature have existed. He persists in maintaining, that the calcaneum, tibia, and femur of the giant Teutobochus, when joined to each other, were more than eleven feet in length.

He next gives letters written to him at the time these bones were discovered, and which seem to confirm the reality both of the tomb and of the bones of the giant Teutobochus. From a letter written by Seignior de Langon, dated St. Marcellin, in Dauphiny, and another by the Sieur Masurier, a surgeon at Beaurepaire, it appears, that silver coins were found along with the bones. The first letter contains the following passage: "As his majesty," says Seignior

de Langon, "is desirous of having the remaining bones of king Teutobochus, and the silver coins found in the tomb, I declare, that your adversaries are ill informed, and that, if they knew the matter more perfectly, they would not entertain any doubts that these bones really belong to the human species. The physicians of Montpellier came here, and would have given any money to purchase the bones. M. le Maréchal de Lesdiguieres made them be carried to Grenoble; and the physicians and surgeons of that place recognised them to be human bones. This fact, of course, can only be denied by persons who are ignorant of the real circumstances."

In this dispute, neither Riolan nor Habicot, the one a physician and the other a surgeon, have had sense enough to give an exact description of the bones in question. Both of them, actuated by passion and a party spirit, have written in a style which destroys all confidence in their assertions. Hence it is extremely difficult to ascertain the species to which these bones really belonged. But, if they were found in a brick tomb, with a stone cover, upon which the words *Teutobochus Rex* were inscribed; if coins were found in this tomb; if it contained but a single skeleton of twenty-four or twenty-five feet in length; and, if Seignior Langon's letter relates nothing but truth, the general fact, *i. e.* the existence of a giant of twenty-four feet high, unless we should suppose a very extraordinary concourse of falsehoods, could not admit of

a doubt. But the fact is by no means proved in a manner so explicit as not to leave room for much hesitation. It is true, that several authors, otherwise worthy of credit, have mentioned giants as large, and even larger. Pliny relates*, that, by an earthquake in Crete, a mountain was split, and discovered a human body of sixteen cubits long, which some ascribed to that of Otus, and others to that of Orion. Sixteen cubits are equal to twenty-four feet, which is the same length with the skeleton of king Teutobochus.

In a memoir of M. le Cat, an academician of Rouen, we have an enumeration of several giants of enormous magnitude; namely, two whose skeletons were found near Athens, of which one was thirty-six and the other thirty-four feet high; another of thirty was found in Sicily, near Palermo, in the year 1548; another of thirty-three feet was likewise found in Sicily, in the year 1550; and another was also found in Sicily, near Mazarino, which was thirty feet long.

These testimonies notwithstanding, it is difficult to believe that men of thirty or thirty-six feet high ever existed: it is perhaps too much to believe in the existence of giants of twenty-four feet high. However, evidences multiply, become more positive, and gradually increase, in proportion as the dimensions decrease. M. le Cat relates, that, in the year 1705, there was

* Lib. vii. cap. 16.

found, near the banks of the river Morderi, at the foot of Mount Crussol, the skeleton of a giant which measured 22½ feet; and that the Dominicans of Valencia have part of the tibia with the joint of the knee.

Platerus, a celebrated physician, asserts, that he saw at Lucerne the skeleton of a man, which was nineteen feet in length.

The giant Ferragus, slain by Rolland, nephew to Charlemagne, was eighteen feet high.

In the sepulchral caverns of the island of Teneriffe, a skeleton was found, which measured fifteen feet, and in whose jaws were eighty teeth. These three facts, as well as the preceding, are related in M. le Cat's Essay concerning Giants. He mentions another skeleton found in a ditch near the convent of the Dominicans at Rouen, the skull of which held a bushel of corn, and the bone of the leg was four feet long: the whole body, of course, must have been from seventeen to eighteen feet in length. Upon the tomb of this giant, the following inscription was engraved: "Here lies the noble and puissant seigniur le chevalier Ricon de Valmont, together with his bones."

In the Journal Littéraire of Abbé Nazari, we are told, that, in High Calabria, in the month of July, 1665, there was dug out of the gardens of Signior de Tiviolo, a skeleton of eighteen Roman feet long; that the head was 2½ feet; that each grinder weighed about an ounce and a third, and the other teeth three quarters of an

ounce; and that this skeleton was bedded in a mass of bitumen.

Hector Boethius, in his History of Scotland, relates, that the bones of a man, ironically called Little John, are still preserved, who was supposed to have been fourteen feet high.

In the Journal des Savans, *anno* 1692, there is a letter from P. Gentil, professor of philosophy at Angers, in which he says, that, having been informed of a gigantic body discovered nine leagues from the town of Lassé, he went to the spot to satisfy himself concerning the truth of the fact. He learned from the curate of the place, that, in digging his garden, a sepulchre was discovered which contained a body of seventeen feet two inches long. There was no skin on the body. This body had others between its arms and legs, which might have been the person's children. In the same place, there were discovered fourteen or fifteen other sepulchres, some of them ten feet, others twelve, and others fourteen feet long, which contained bodies of the same dimensions. The sepulchre of this giant continued exposed to the air more than a year; but, as it attracted too many visitors to the curate, he again covered it with earth, and planted three trees in the place. These sepulchres were constructed with a stone which resembled chalk.

Thomas Mollineux saw, in a cabinet at Leyden, a prodigious human frontal bone. From its junction with the nose to the sagittal suture,

it was $9\frac{1}{10}$ inches; its length was $12\frac{2}{10}$ inches, and its thickness half an inch, *i. e.* in every dimension it was double that of an ordinary frontal bone. Hence the person to whom this gigantic bone belonged must have been twice the common size of a man, or at least eleven feet high. This bone was unquestionably human; and it seemed not to have acquired this uncommon magnitude by the effects of any disease; for its thickness was exactly proportioned to its other dimensions, which never happens in diseased bones *.

M. Klein tells us, that he saw, in the cabinet of M. Witreu at Amsterdam, a frontal bone, from the dimensions of which it appeared, that the person to whom it appertained must have been thirteen feet four inches high, *i. e.* about 12½ French feet †.

After all these facts, I shall leave my readers in the same embarrassment as myself, with regard to the real existence of giants of twenty-four feet in length. I cannot persuade myself, that, at any time, or by any circumstances whatever, the human body could be elevated to such immoderate dimensions. But, at the same time, it is unquestionable, that giants of ten, twelve, and perhaps even of fifteen feet high, have existed; and it is almost certain, that, in the primæval ages of nature, not only gigantic individuals, but even permanent and successive

* Phil. Trans. num. 168, art. ii.

† Ibid. num. 456, art. iii

races of giants, were produced, of which that of the Patagonians is the only remaining example.

To prove that some of the fishes and plants found in coal and slate belong to species which no longer exist, the count de Buffon produces the following facts and observations:

With regard to this subject, we shall remark, with M. Lehman*, that there are no impressions of plants in slate, except when it accompanies pit-coal; and that, on the contrary, impressions of fishes are seldom found but in coppery slates.

It has likewise been remarked, that, in the district of Mansfield, the beds of slate which contain petrified fishes, are covered with a stratum of stones called stinking stones. This stratum is a species of gray slate, which has derived its origin from stagnant water, where the fishes had corrupted before they were petrified†.

M. Hoffman, when treating of slates, says, that the petrified fishes found in these stones have not only been living creatures, but that the strata of slate have originated from muddy water, which, after fermenting and petrifying, subsided in thin laminæ or beds.

"In the slate of Angers," says M. Guttard,

* Tom. iii. p. 407.

† Leeberoth, Journal Oeconomique, Juillet, 1752.

"there are sometimes impressions of plants and fishes, which merit the greater attention, because the impressions of the plants represent marine fuci, or sea wreck, and those of the fishes represent different species of the crustaceous tribes, the impressions of which are more rare than those of scaly fishes, or shells." He adds, "that, after consulting several authors who treat of fishes and crustaceous animals, he could not discover any of them that resembled the impressions in question, except the sea louse, which has some resemblance to them; but it has thirteen rings, and the impressions on the slates have only seven or eight: the impressions of these fishes are generally interspersed with a whitish pyritous substance. It is remarkable, that in the slates of Angers, as well as in those of other countries, the impressions of fishes are frequent, and those of shells are exceedingly rare, whilst the latter are very common in limestone *."

Many proofs might be given that all pit-coal is composed of the spoils of vegetables, mixed with bitumen and sulphur, or rather with the vitriolic acid, which is perceived when the coal is burning. We often find a great quantity of vegetables in the upper strata of coal; and in proportion as we descend, we see traces of the decomposition of the same vegetables. There are species of coal which are not fossil wood: that found at Sainte Agnés, near Lons-le-Saunier,

* Mem. de l'Acad. des Sciences, ann. 1757, p 52.

has a perfect resemblance to logs or trunks of fir, in which we distinctly perceive the marks of each year's growth, as well as the pith. These trunks differ only from common fir by being somewhat oval, and by their rings being concentric ellipses. They exceed not a foot in circumference, and their bark is very thick and full of furrows, like that of old firs. But the bark of common firs, of the same size, is always smooth.

"I found," M. de Gensanne remarks, "several veins of this kind of coal in the diocese of Montpellier: here the trunks are very large; their texture resembles that of chesnut trees from three to four feet in circumference. These fossils, when burning, have only a slight odour of asphaltum. Their flame and embers resemble those of wood. They are found near the surface of the earth, and commonly indicate the existence of real pit-coal at greater depths *."

These ligneous coals ought to be regarded as wood deposited in a bituminous earth, from which they derive their fossil quality. They are found only in earths of this kind, and always near the surface. They sometimes form the stratum immediately above the seams of real coal. Some of them, which have been impregnated with a small quantity only of bitumen, preserve the shades and colour of wood. "I found this species," says M. de Gensanne, "at Cazarets, near Saint Jean de Culcul, four leagues from Montpellier. But,

* Hist. Nat. du Languedoc, par M. de Gensanne, tom. i. p. 20.

when broken, this fossil commonly presents a smooth surface, perfectly similar to that of jet. In the same canton, near Ascras, there is fossil wood changed into a white ferruginous pyrites. The mineral matter occupies the heart of the wood; and we distinctly perceive the woody substance furrowed and partly dissolved by the mineral acid *.

After such proofs, related by M. de Gensanne himself, who is otherwise a good mineralogist, I acknowledge, that I was surprised to see him ascribe the origin of coal to clay more or less impregnated with bitumen. This notion is not only refuted by his own facts, but we shall be convinced by those I am about to relate, that we ought to attribute the origin of every species of coal to the spoils of vegetables mixed with bitumen.

I agree with M. de Gensanne, that neither this fossil wood nor turf can be considered as coal completely formed. That found near Lonsle-Saunier has been recently examined by the president de Ruffey, a learned academician of Dijon: he remarks, that this fossil wood makes a near approach to the nature of pit-coal; and that it is found within two or three feet of the surface through an extent of two leagues; that it is from three to four feet thick; that we easily distinguish the species of wood to be oaks, horn beams, and trembling poplars; that this wood is sometimes in the form of bundles or faggots;

* Hist. Nat. du Languedoc, tom. i. p. 54.

that the bark of the logs is well preserved; that the annual circles, the cuts made by the axes, and, at different distances, collections of chips are plainly distinguishable; that this wood converted into coal is excellent for soldering iron; that, when burning, it diffuses a fetid odour; and that alum has been extracted from it *.

"Near the village called Beichlitz, about a league from the town of Halle, two strata, composed of a bituminous earth and fossil wood (of which there are several mines in the country of Hesse), were discovered. It is similar to that found in the village of Sainte Agnés in Franche-comté, two leagues from Lons-le-Saunier. This mine is in the territory of Saxe. The first stratum lies at the depth of three fathoms and a half, and is from eight to nine feet thick. To arrive at it, we cut through a white sand, then a whitish gray clay, which is three feet thick: still deeper we meet with a considerable thickness both of sand and clay, which cover the second stratum. This stratum is only from three and a half to four feet thick. We sounded deeper, but found no other strata of that kind.

"These strata are horizontal; but they sink or rise nearly in the same manner as common strata. They consist of a brown bituminous earth, which is friable when dry, and resembles corrupted wood. Pieces of wood of all

* Mem. de l'Acad. de Dijon, tom. i. p. 47.

sizes are found, which, when taken from the mine, where they are soft, must be cut with an axe. This wood, when dry, breaks easily. When broke, it shines like bitumen; but we distinctly perceive in it the whole organization of wood. It is less abundant than the bituminous earth, and the workmen lay it aside for their own use.

"A bushel or two quintals of bituminous earth sells for eighteen or twenty French sous. In these strata there are pyrites; they are of a vitriolic nature; when exposed to the air they effloresce and turn white: but the bituminous matter is of little value, as it gives but a feeble heat *."

Hence this species of fossil wood, found so near the surface of the earth, must be a much more recent production than common pit-coal, which is almost constantly sunk very deep. But this idea does not preclude the ancient coal from being formed of the spoils of vegetables; since, in the deepest coal mines, we recognise woody substances, and several characters which belong to vegetables only. Besides, there are some examples of fossil wood found in large masses, and in extensive beds, under strata of free-stone and calcarious rocks. Hence there is no other difference between real pit-coal and those charred woods, but what arises from the degree of decomposition, and from a greater or smaller impregnation with bitumen. The basis of their

* Voyages Metalurgiques de M. Jars, p. 320

substance is the same, and both derive their origin from the spoils of vegetables.

M. le Monnier, one of the king's physicians, and a learned botanist, found, in the schist or false slate, which traverses a large field of pit-coal in Auvergne, the impressions of several ferns, almost the whole of which were unknown to him: he only thought that he could distinguish the impression of the leaves of the osmund-royal, of which he saw but one example in all Auvergne *.

It were to be wished that botanists would examine more accurately the impressions of plants found in pit-coal and in slate. The impressions of plants, as well as those of crustaceous animals, shells, and fishes, found in these minerals, should be drawn and engraved; for all this labour is necessary to enable us to determine the actual or the past existence of these species, or even their relative antiquity. At present, we are satisfied, that most of them are unknown; and that, in those which have been referred to known species, the differences are always so great as to create hesitation.

The count de Buffon remarks, that the motion of the waters from east to west has diminished the surface of the earth on the west side; and that, in every continent of the globe, the declivity is more rapid on the west than on the east coasts. This is evident in the continent of America, the declivities of which are extremely

* Observations de Hist. Nat. par M. le Monnier, p. 193.

rapid and abrupt toward the western seas; but, toward the eastern coasts, the lands stretch by a gentle declivity, and generally terminate in large plains. In Europe, the line that forms the summit of Great Britain, which runs from north to south, is much nearer the Western than the Eastern Ocean: for the same reason, the seas to the west of Britain and Ireland are much deeper than the sea which separates Britain and Holland. The ridge of Norway is much nearer the ocean than the Baltic Sea. The mountains which form the general summit of Europe are much higher towards the west than the east; and, if we take a part of this summit, from Switzerland to Siberia, it is much nearer the Baltic and White Seas, than the Black Sea and the Caspian. The Alps and Appennines are nearer the Mediterranean than the Adriatic Sea. The chain of mountains which runs from Tyrol to Dalmatia, and as far as the Morea, in a manner skirts the Adriatic Sea; but the opposite coasts are much lower. In Asia, if we follow the chain which extends from the Dardanelles to the Strait of Babelmandel, we shall find that the summits of Mount Taurus, of Libanus, and of all Arabia, skirt the Mediterranean and the Red Seas; and that, to the east, there are vast territories where the long-coursed rivers run, and at last empty themselves in the Persic Gulf. The summit of the famous mountains called the Gauts approaches nearer to the western than the eastern seas. The ridge which extends from the west frontiers of China to the point of Malacca,

the chain of Mount Atlas sends rivers to the sea of the Canaries, whose courses are much shorter than those which run into the interior parts of the continent; and, after traversing vast tracts of country, lose themselves in lakes or great marshes. The high mountains to the west of Cape Verd, and through all Guinea, after turning round Congo, join the mountains of the Moon, and stretch as far as the Cape of Good Hope, occupy pretty uniformly the middle of Africa: we shall perceive, however, on examining the sea to the east and west, that the sea on the east is not deep, and is interspersed with a great number of islands; whilst, to the west, it is deeper, and has but few islands; so that the deepest places of the western sea are much nearer this chain of mountains than the deepest places of the eastern or Indian seas.

Hence we see that, in general, all the points of partition in the great continents are always nearer the west than the east seas; that the plains of these continents are always lengthened toward the east, and shortened toward the west; that the seas on the west coasts are deeper, and have fewer islands than those on the east; and that in all these seas, the west coasts of the islands are always higher, and the seas which wash them deeper than those on the east.

We are next told, that there are animals, and even men so brutish, that they rather languish

in the ungrateful soil where they were brought forth, than take the trouble of removing to a more comfortable situation. Of this, says the count de Buffon, I can give a striking example: the Maillés, a small savage nation in Guiana, near the mouth of the river Ouassa, have no other habitation than trees, upon which they dwell during the whole year, because their country is always more or less covered with water. They never descend from these trees, except when they go in canoes in quest of subsistence. This is a singular example of a stupid attachment to a native country; for these savages, in order to procure habitations on land, have only to remove a few leagues from those drowned savannahs which gave them birth, and which they obstinately refuse to abandon. This fact is mentioned by some voyagers*, and has been confirmed to me, by several witnesses, who have lately seen this small nation, which consists of 300 or 400 savages. They keep themselves above the water by means of the trees. There they remain the whole year. During the eight or nine rainy months, their country is a large sheet of water; and, during the four summer months, their soil consists of a dirty mud, upon which a crust of five or six inches

* The Maillés, one of the savage nations of Guiana, dwell along the coast. Their country is often covered with water. They, therefore, build their cabins upon trees, to the feet of which they fasten their canoes, in which they sail in quest of subsistence; Voyage de Desmarchais, tom. iv. p. 352.

thick is formed. This crust is rather composed of herbage than of earth, under which is a considerable depth of stagnant and stinking water.

The Caspian Sea, the count de Buffon remarks, was formerly much larger than it is at present.—— "In traversing," says M. Pallas, "the immense deserts which lie between the Wolga, the Jaïk, the Caspian Sea, and the Don, I observed, that these *steppes*, or sandy deserts, are every way surrounded with an elevated border, which embraces a great part of the beds of the Jaïk, Wolga, and Don; and that these deep rivers, before they penetrated this inclosing belt, were full of islands and shoals, till they began to fall into the deserts where the great river Kuman loses itself in the sands. From these observations I conclude that *the Caspian Sea has formerly covered all these deserts*; that it anciently had no other margins than those elevated belts which every where surround the deserts; and that it has communicated, by means of the Don, with the Black Sea, even supposing this sea, as well as that of Azoff, had never made a part of it*.

M. Pallas is unquestionably one of our most

* Journal Historique et Politique, mois de Novembre, 1773, art. Petersbourg.

learned naturalists; and it is with the greatest pleasure that I see him here entirely of my opinion with regard to the ancient extent of the Caspian, and the probability that it formerly communicated with the Black Sea.

There have been greater and more frequent revolutions in the Indian Ocean than in any other part of the globe. But, says the count de Buffon, tradition has only handed down to us the submersion of Taprobana.——The most ancient tradition we have of the sinking of countries in the south is that of the loss of Taprobana, of which the Maldivas and Laquedivas are supposed to have been formerly a part. These islands, as well as the rocks and banks which prevail from Madagascar to the point of India, seem to indicate the summits of countries that united Africa to Asia; for almost all of these islands have, on the north side, lands and banks which stretch very far under the waters.

It likewise appears, that the islands of Madagascar and Ceylon were formerly united to the adjacent continents. Most of these separations and revolutions in the southern seas have been produced by the sinking of caverns, by earthquakes, and by explosions of subterraneous fires. But lands have also been carried off by the slow and gradual movement of the waters from east to

west. The places where these effects are most apparent are the regions of Japan, of China, and of all the eastern parts of Asia. The seas situated to the west of China and Japan seem to be accidental productions, and perhaps more recent than our Mediterranean.

The islands of Sunda, the Moluccas, and the Philippines, present nothing but countries which have been overturned; and they are still full of volcanos. There are many volcanos in the Japanese islands: and Japan is reputed to be more subject to earthquakes than any other part of the globe: it also gives rise to a number of hot fountains. The greater part of the islands in the Indian Ocean present only peaks or summits of detached mountains, which continually vomit fire. The isles of France and Bourbon appear to be two of these summits: they are almost entirely covered with matters rejected by volcanos. These two islands, when first discovered, were uninhabited.

In Guiana, our author remarks, the rivers are so near each other, and at the same time so swelled and rapid during the rainy season, that they carry down immense quantities of mud, and deposit them on all the low grounds, and on the bottom of the sea. The coasts of French Guiana are so low, that they may rather be regarded as beaches totally covered with mud, and having an almost imperceptible declivity. This mud ex-

tends to a great distance at the bottom of the sea. Large vessels cannot approach the river Cayenne without striking; and ships of war are obliged to remain two or three leagues from the land. This mud extends along the whole margin of the sea from Cayenne to the river of the Amazons. In this great extent of mud there is no sand, and berry-bearing alders are frequent all along the coast. But seven or eight leagues above Cayenne, westward as far as the river Marony, we find some creeks, the bottoms of which consist of sand and rocks, which give rise to breakers. The mud, however, covers the greater part of these rocks, as well as the beds of sand; and it is thicker in proportion as it recedes from the margin of the sea. These small rocks prevent not the ground from having a very gentle descent for several leagues on land. This part of Guiana, to the north-west of Cayenne, is more elevated than the lands to the south-east. Of this fact we have good evidence; for all along the borders of the sea we find large drowned savannahs, most of which are dry in the north-west, whilst they are totally covered with sea water in the south-east parts. Beside these lands actually drowned by the sea, there are others more distant, which have likewise been formerly drowned. In some places we also find savannahs of fresh water; but they produce no alders, but many palm trees. On all these low coasts, not a stone is to be seen. The tide rises seven or eight feet, though it is opposed by the currents; for they are all directed toward the Antilles. When the

waters of the rivers are low, the tide is very perceptible, as high up the rivers as forty, and even fifty leagues. But, during the rainy season, when the rivers are swelled, the tide is scarcely perceptible at the distance of a league or two, so great is the rapidity of the waters; and their impetuosity is greatest during the reflux.

Upon the sandy bottoms of these creeks, the sea turtles deposit their eggs; and they never frequent the muddy places; so that, from Cayenne to the river of the Amazons, there are no turtles; and the people go to fish them from the river Courou to the Marony. The mud appears to gain ground daily on the sand; and, in the progress of time, the north-west coast of Cayenne will be covered with it as well as the south-east; for the turtles, who will deposit their eggs in sand only, gradually retire from the river Courou; and, for some years past, the fishers are obliged to search for them near the river Marony, the sands of which are not yet covered.

Beyond the savannahs, some of which are dry and others drowned, there is a chain of hills that are all covered with a great depth of earth, and every where planted with forests. These hills are generally from 350 to 400 feet high. But, about ten or twelve leagues farther up the country, they are perhaps double this height. Most of these mountains are evidently extinguished volcanos. At the top of one of them, called La Gabrielle, there is a small lake, in which are a number of alligators, whose species seems to

have been preserved from the time that the sea covered this hill.

Beyond Mount Gabrielle, we find only small valleys, little hills, and volcanic matters, not in large masses, but in small blocks. The most common stone, blocks of which are carried down by the waters as far as Cayenne, is that called *beetle-stone*. It is not a stone, but the lava of a volcano. It has received the name of *beetle-stone*, because it is full of holes, which these insects inhabit.

Of the Glaciers.

In the highest regions of the Alps, the waters which proceed from the annual meltings of the snow, freeze in every direction, and on all the points of the mountains from their bases to their summits, and especially in the valleys, and on the declivities of those that are collected together in groups: in this manner, the waters have formed in these valleys some mountains which have rocks for their nucleus, and others that consist entirely of ice: these mountains are six, seven, and even eight leagues long by one in breadth, and often from 1,000, to 1,200 fathoms high. These enormous masses of ice are continually extending farther along the valleys; for though, in warm and rainy seasons, their progress is not only stopped, but their size diminished, the magnitude of the glaciers is perpetually augmenting.

Under the equator, the point of congelation, in detached mountains, is fixed at the height of 2,440 fathoms. But this is no rule for groups of mountains which are frozen from their summits to their base, and never thaw. In the Alps, the point of congelation in detached mountains is ascertained to be at the height of 1,500 fathoms, and all below this point thaws completely. But those which are grouped together freeze at a smaller height, and thaw from their top to their base; which shows how much the degree of cold is augmented by immense masses of congealed matter confined within a narrow compass.

The whole frozen mountains of Switzerland, when taken together, occupy an extent of sixty-six leagues from east to west, measured in a straight line from the western borders of the canton of Vallis towards Savoy, to the eastern borders of the canton of Bendner towards Tyrol. They form an interrupted chain, several arms of which extend, from north to south, about thirty-six leagues. The great Gothard, the Fourk, and the Grimsel, are the highest mountains in this quarter: they occupy the centre of those chains which divide Switzerland into two parts. They are perpetually covered with snow and ice; from which circumstance they have received the general denomination of *glaciers*.

The glaciers are divided into frozen mountains, valleys of ice, fields of ice, or frozen seas, and *gletchers*, or heaps of icy flakes or plates.

The frozen mountains are those immense

masses of rocks which reach the clouds, and are perpetually covered with ice and snow.

The valleys of ice are those depressions between the mountains which are much more elevated than the inhabited valleys. They are always filled with snow, which accumulates, and forms masses of ice several leagues in length. These masses join the high mountains.

The fields of ice, or frozen seas, which lie along the mountains, have a gentle declivity. They cannot be called valleys, because they are not sufficiently depressed. They are covered with a great thickness of snow. These fields receive water from the melting of the snow, which descends from the mountains, and afterwards freezes. The surface of these fields alternately melts and freezes; and the whole are covered with thick beds of snow and ice.

The gletchers are heaps of flakes or plates of ice formed by the snows, and precipitated from the mountains. These snows freeze again, and are interwoven in various manners: this circumstance has given rise to the division of gletchers into mounts, mantlings, and walls of ice.

The mounts of ice rise between the summits of the high mountains: they themselves form mountains; but they contain no rocks. They are composed entirely of ice, and are sometimes several leagues in length, one league broad, and half a league thick.

The mantlings are formed in the superior valleys, and upon the sides of the mountains, which are covered with ice, having folds resembling

drapery: they send their superfluous waters into the lower valleys.

The walls of ice are rugged mantlings, which terminate the flat valleys, and appear, at a distance, like troubled seas, whose waves have been suddenly arrested and frozen. These walls consist not of irregular points: they often form columns, pyramids, and enormous towers composed of several sides. These towers are sometimes hexagonal, and of a blue or greenish colour.

On the sides, and at the foot of the mountains, masses of snow are formed, which are afterwards moistened with the water from the melted snows, and then covered with fresh accumulations. We likewise see plates of ice collected in heaps, which belong neither to the frozen valleys nor the mountains of ice. Their position is either horizontal or inclined. These detached heaps are called *beds* or *strata* of ice.

Several of these mountains of ice are undermined by the interior heat of the earth, which gives rise to currents of water that melts their inferior surfaces. They then, by their own weight, sink insensibly, and their height is restored by the waters, snow, and ice, which again successively cover them. These sinkings often produce horrible crashings. The crevices which open in the ice form precipices which are both numerous and full of danger. These abysses are the more treacherous and baneful, because they are generally covered with snow. Travellers, and hunters who chase the fallow deer, the chamois goat, &c., or those who search

for crystals, are often swallowed up by these gulfs, and again thrown upon the surface by the waters which run at their bottoms.

Gentle rain quickly dissolves snows: but all the water which proceeds from them falls not into these gulfs. A great part of it freezes on the surface of the ice, and augments its volume.

The warm south winds, which generally prevail in the month of May, are the most powerful agents in destroying the snows and ice. Their melting is announced by the crashing of the frozen lakes, and the dreadful noise produced by the shock of stones and ice, which in horrible confusion roll down from the tops of the mountains, and by torrents of water that fall from the rocks of more than 1,200 feet high.

The heat of the sun has little effect upon the snow and ice. Experience has proved, that ice which has existed a long time under an enormous weight, and in accumulated degrees of cold, is so dense, and so completely deprived of air, that, when small pieces of it are exposed to the greatest heat of the sun, during a whole day, they scarcely melt.

Though the glaciers melt partially every summer, though the winds and the heat of certain years destroy the accumulation of several preceding years; yet it is certain that these *glaciers constantly augment in all their dimensions.*

This fact is ascertained by the annals of the country, by authentic deeds, and by invariable tradition. Independent of these authorities and of daily observation, the progressive increase

of the glaciers is proved by *forests of trees which have been absorbed by the ice, some of whose tops still appear above the surface of the glaciers:* these, as well as *the tops of steeples belonging to a village* that had been buried under the snows, and which are still visible after uncommon meltings, are irrefragable evidences of the gradual progress of the glaciers. This progression can proceed from no other cause than an augmentation in the degree of cold, which increases in proportion to the masses of accumulated ice. It is likewise certain, that, in the glaciers of Switzerland, the cold is at present more intense, though it continues shorter than in Iceland, the glaciers of which, as well as those of Norway, have a great relation to those of Switzerland.

The substance of the frozen mountains of Switzerland is similar to that of all other high mountains. The nucleus is a vitreous rock, which reaches to their summit. The parts below, which had been covered with the ocean, are composed of calcarious stone, as well as the whole substance of the mountains of an inferior order, which are disposed in groups at the foot of the primitive glacier mountains. Lastly, these calcarious masses have slate, produced by the sediments of the waters, for their basis.

The vitreous masses are pure rock, granite, and quartz. Their fissures are filled with metals, semi-metals, mineral substances, and crystals.

The calcarious masses are lime-stone, marbles of every species, chalk, gypsum, spar, alabastar, &c.

The slaty masses consist of slates of various qualities and colours, which contain plants and fishes, and are often situated at considerable heights. Their strata are not always horizontal. They are often inclined, sometimes sinuated, and in particular places perpendicular.

We cannot entertain a doubt concerning the ancient abode of the sea upon the glacier mountains. The immense quantity of shells, as well as the slate and other similar stones, found in these mountains, fully ascertain this point. These shells are either distributed in tribes, or different species are blended together, and they are found at very great heights.

It is probable, that, at a very remote period, the glaciers had not been formed on these mountains, not even when the ocean abandoned them; though it appears, by their great distance from the sea, which is near a hundred leagues, and by their excessive height, that they were the first that arose above the water in the continent of Europe. They have likewise had their volcanos. Mount Myssenberg, in the canton of Schwitz, seems to have been the last volcano that was extinguished. The two principal summits, which are very high and detached, terminate in cones, like all the mouths of volcanos; and we still see the crater of one of these cones, which is very deep.

M. Bourrit, who had the courage to make a number of expeditions in the glaciers of Savoy, remarks, "that the increase of all the glaciers in the Alps is unquestionable; that the quantity

of snow that falls during the winters far surpasses that which melts in the summers; that the same cause not only subsists, but the masses of snow already formed must always augment, because this effect is a necessary result of that cause. Hence the glaciers must always continue to have a progressive increase*."

The same indefatigable observer, when treating of the glatchers or glaciers with prominent points, says, "that they appear to augment daily; that the ground they now occupy was some years ago a cultivated field; and that the ice still continues to augment †." He relates, that the growth of the ice is evident, not only in this place, but in several others; that the inhabitants remembered a former communication between Chamounis and Val-d'Aost, which is now totally shut up by the ice; that the ice, in general, must have first accumulated by stretching from summit to summit, and then from one valley to another; and that, in this manner, a communication has been formed between the ice of Mount Blanc and those of the other mountains of Vallais and of Switzerland ‡. It appears," says he, "that all these mountainous countries were not anciently so much filled with ice and snow as they are at present. . . . . It is only a few centuries since various calamities have been occasioned

* Descript. des Glaciers de Savoie, par M. Bourrit, p. 111, 112.

† Descript. des Aspects du Mont Blanc, par le même, p. 8.

‡ Ibid, p. 13 et 14.

by the accumulation of snows and ice in several valleys, and by the precipitation of mountains and rocks. It is only from these accidents, which are very frequent, and from the annual accumulations of the ice, that we are enabled to account for what history relates concerning the ancient inhabitants of this country *."

Of the North-East Passage.

Notwithstanding what has been advanced by the Russians, it is extremely doubtful that they ever doubled the northern point of Asia. M. Engel, who regards the north-west passage by Hudson's and Baffin's Bay as impossible, appears, on the contrary, to be persuaded, that a shorter and more certain passage will be found by the north-east. To the feeble reasons he gives in support of this opinion, he adds a remark of M. Gmelin, who, when speaking of the experiments made by the Russians, in order to discover this north-east passage, says, "that the manner in which they proceeded in making these discoveries will astonish the whole world, after an authentic relation of them shall be made public, which depends solely on the pleasure of the empress."——"There can be nothing astonishing," says M. Engel, "in this subject, except it be to learn that a passage, which was for-

* Descript. des Aspects du Mont Blanc, par M. Bourrit, p. 62 et 63.

merly regarded as impossible, is now found to be extremely practicable. This is the only fact," he adds, "which can surprise those whom the Russians have endeavoured to terrify by relations published for the purpose of repelling navigators from the attempt *," &c.

I shall, in the first place, remark, that we ought to be well ascertained with regard to facts, before we throw an imputation of this kind upon the Russian empire. In the second place, the remark seems to be ill founded; for the words employed by M. Gmelin may admit of an opposite interpretation from that given of them by M. Engel; namely, "that we will be astonished when we shall learn that no practicable passage exists by the north-east." Independent of the general reasons I have given, I am confirmed in this opinion by the following circumstance: the Russians themselves, in their late experiments, uniformly ascend by Kamtschatka, and never descend by the point of Asia. Captains Bering and Tschirikow, in the year 1741, reconnoitred the coast of America as far as the fifty-ninth degree; but neither of them sailed northward along the coasts of Asia. This fact is a sufficient proof, that the passage is not so practicable as M. Engel supposes; or, rather, that the Russians are satisfied that it is not practicable; for, if otherwise, their navigators would have been sent by this route, instead of making them take their departure from Kamtschatka, in order to discover the west of America.

* Hist. Gen. des Voyages, tom. xix. p. 415.

M. Muller, who was sent by the empress along with M. Gmelin to Siberia, is of a very different opinion from M. Engel. After comparing all the relations on this subject, M. Muller concludes by remarking, that there is only a very small separation between Asia and America; and that this strait contains several islands, which serve as common stations to the inhabitants of both continents. This opinion, I believe, is well founded; and, in support of it, M. Muller has collected a great number of facts. In the subterraneous abodes of the inhabitants of the island of Caraga, we see beams made of large pines, which neither this island nor the adjacent countries of Kamtschatka produce. The inhabitants say, that this wood is driven upon their coasts by the east wind. On the coasts of Kamtschatka, masses of ice are driven for several days together during the winter. At certain seasons, flights of birds arrive, and, after staying some months, return to the east, from whence they came. Hence the continent opposite to that of Asia, toward the north, descends as far as Kamtschatka. This continent must be the west of America. M. Muller *, after giving an abridgement of five or six voyages attempted by the North Sea, with a view to double the north point of Asia, concludes, that every circumstance announces the impossibility of this navigation, which he proves by the following arguments: this na-

* Hist. Gen. des Voyages, tom. xviii. p. 484.

vigation must be performed in summer: the distance from Archangel to the Oby, and from this river to Jenissy, requires a whole season. The passage by Waygait has cost infinite labour to the British and Dutch. In going through this icy strait, we meet with islands which block up the road; and the continent, which forms a cape between the rivers Piasida and Chatanga, and advances beyond the seventy-sixth degree of latitude, is likewise bordered with a chain of islands, which scarcely leave a passage for navigation. If we want to remove from the coasts, and to reach the open sea toward the pole, the almost immoveable mountains of ice found at Greenland and Spitzbergen, seem to indicate a continuity of ice as far as the pole. If we want to go along the coasts, *this navigation is more difficult now than it was a hundred years ago.* There the waters of the ocean are sensibly diminished: we still see, at a distance from the shoals, along the Frozen Sea, wood that had been thrown upon the lands which formerly bounded the ocean. These shoals have so little depth, that very flat boats can alone be used in them: such boats are too weak to resist the ice; neither can they contain provisions sufficient for a long navigation. Though the Russians have resources for sailing these cold seas superior to those of most other European nations, yet in none of the voyages attempted upon the Frozen Sea has a passage been discovered between Europe or Asia to America. It is only by departing from Kamtschatka, or some other more easterly point of

Asia, that the westerly coasts of America have ever been discovered.

Captain Bering took his departure from Port Awatscha in Kamtschatka, on the 4th day of June, 1741. After sailing south-east, and then north-east, he discovered, on the 18th of July, the continent of America in latitude 58° 28′. Two days after, he anchored near an island in the mouth of a bay, from whence he discovered two capes, the one to the east he called Saint Elie, and the other to the west Saint Hermogene. He then dispatched Chitrou, one of his officers, to reconnoitre the gulf which he had entered: they found that it was interspersed with islands, on one of which they saw deserted cabins made of planks well joined, and even chamfered. They conjectured that this island might have been inhabited by some people from the continent of America. M. Steller, who was sent to make observations on these new discovered lands, found a cave, in which were a quantity of smoked salmon, ropes, furniture, and other utensils. Advancing still farther, he saw the Americans flying from him. He next perceived a fire on a distant hill. The savages had unquestionably retired thither: a rugged and steep rock covered their retreat *.

After relating these facts, it is easy to perceive, that it is only by taking their departure from Kamtschatka that the Russians can carry on commerce with China and Japan, and that it is

* Hist. Gen. des Voyages, tom. xix, p. 37 &c.

equally difficult, if not impossible, for the other nations of Europe to pass by the north-east seas, the greater part of which are entirely frozen. Hence I cannot hesitate in repeating, that the only possible passage is by the north-west, at the bottom of Hudson's Bay; and that this is the place where all future attempts to discover this useful passage ought to be made.

After the preceding sheets had been printed, I received from M. le comte Schouvaloff, that great statesman, whom all Europe esteems and respects, an excellent memoir composed by M. de Domascheneff, president of the Imperial Society of Petersburg, and to whom the empress has assigned the department of every thing relating to arts and sciences. This illustrious person has likewise sent me a copy of the chart drawn by the pilot Otcheredin, in which are represented the tracks and discoveries he made in the years 1770 and 1773, between Kamtschatka and the continent of America. M. de Domascheneff, in his memoir, remarks, that this chart of the pilot Otcheredin is most exact, and that the one published in the year 1773 by the Academy of Petersburg, requires several amendments, especially with regard to the position of the islands and the pretended Archipelago, which are represented between the Aleutes or Aleoutes islands, and those of Anadir, otherwise called Andrien. The chart of Otcheredin seems to show, that these two groups of islands, the Aleutes and the islands of Andrien, are separated by an open sea of more than 100 leagues broad.

M. de Domascheneff assures us, that the great general chart of the Russian empire, published in the year 1777, gives an accurate representation of all the coasts on the northern extremity of Asia inhabited by the Tschutschis: he says, that this chart was executed from the most recent discoveries made in the last expedition of Major Pawluski against that people. "This coast," says M. de Domascheneff, "bounds the great chain of mountains which separate Siberia from the south of Asia, and terminates by dividing itself between the chain that stretches through Kamtschatka and those which occupy the territories between the rivers that run to the east of the Lena. The known islands between the coasts of Kamtschatka and those of America are mountainous, as well as the coasts of Kamtschatka and those of the continent of America. Hence there is a distinct continuation between the chains of mountains belonging to both continents, the intervals of which, perhaps less considerable formerly, may have been enlarged by the decaying of rocks, by the perpetual currents which run from the Frozen Sea toward the Southern Ocean, and by the revolutions which the earth has undergone."

But this sub-marine chain, which joins the lands of Kamtschatka to those of America, is more southerly, by seven or eight degrees, than that of the islands of Anadir or Andrien, which, from time immemorial, has served the Tschutschis as a passage to America.

According to M. de Domascheneff, it is cer-

tain, that this voyage, from the point of Asia to the continent of America, is performed by oars, and that these people go there to dispose of Russian iron works to the Americans; that the islands in this passage are so frequent, that the sailors may sleep every night on land; and that the continent of America, with which the Tschutschis traffick, is mountainous, and covered with forests, which are full of foxes, martins, and sables, the qualities and colours of whose furs are totally different from those of Siberia. These northern islands, situated between the two continents, are known to the Tschutschis only. They form a chain between the most eastern point of Asia and the continent of America, under the sixty-fourth degree of latitude; and this chain is divided by an open sea, from the other more southern chain formerly mentioned, which lies between Kamtschatka and America, and is under the fifty-sixth degree. The islands of this second chain the Russians and inhabitants of Kamtschatka frequent in quest of sea otters, and black foxes, whose furs are very precious. Before the year 1750, even the most eastern of the islands which compose this chain were known. One of these islands bears the name of captain Bering, and another, adjacent to the former, is called the island of Medcnoi. We next meet with the islands of Aleutes or Aleoutes. The two first are situated a little above, and the last a little below the fifty-fifth degree of latitude. About the fifty-sixth degree, we find the islands of Atkhou and Amlaïgh, which are the first of

the chain called the islands of Foxes: they extend as far to the north-east as the sixty-first degree of latitude. These islands have received their denomination from the prodigious number of foxes found in them. The two islands of captain Bering and Medenoi were uninhabited when first discovered. But, in the islands of Aleutes, though advanced farther to the east, more than sixty families were found, whose language had no relation either to that of Kamtschatka or to any of the oriental languages of Asia: it is a dialogue of the language spoken in the other islands adjacent to America, which seems to indicate that they have been peopled by the Americans, and not by the Asiatics.

The islands called by captain Bering's crew Saint Julian, Saint Theodor, and Saint Abraham, are the same with those which now receive the name of Aleutes. In the same manner, the islands of Chommaghin and Saint Dolmat, discovered by this navigator, form a part of those now called the islands of Foxes.

"The great distance," says M. de Domascheneff, "and the open and deep sea between the islands of Aleutes and those of Foxes, joined to the different direction of the latter, render it probable, that these islands never formed one continued chain, but that the former, with those of Medenoi and Bering, make a chain which comes from Kamtschatka; that the islands of Foxes exhibit another passage to America; and that both of these chains generally lost themselves in the depth of the ocean, and are promontories to

the two continents. The course of the islands of Foxes, some of which are of great extent, is intermixed with rocks and breakers, and continues without interruption as far as the continent of America. But those most adjacent to this continent are very little frequented by the Russian hunters; because they are very populous, and it would be dangerous to sojourn in them. There are several islands in the neighbourhood of America which are still little known. Some ships, however, have penetrated as far as the island of Kadjack, which is very near the continent of America. We are assured of this fact by the relation of the islanders; and other circumstances confirm the truth of their assertion: all the islands that lie more to the west, produce only dwarfish and misshapen shrubs, which the winds from the open sea prevent from rising higher. The island of Kadjack, on the contrary, and the small adjacent islands, produce groves of alder trees, which seem to indicate that they are less exposed, and that they are sheltered on the north and east by a neighbouring continent. Besides, in Kadjack, we find fresh water otters, which appear not in the other islands; and we likewise find a small species of marmot, which seems to be the marmot of Canada. Lastly, we discover, in that island, traces of the bear and wolf; and the inhabitants clothe themselves with rein-deer's skins, brought to them from the continent of America, to which they lie very contiguous.

"From a voyage to the island of Kadjack, con-

ducted by one Geottof, we learn, that the continent of America is called *Atakthan* by the islanders: they say, that this great land is mountainous and covered with forests; that it is situated to the north of their island; and that the mouth of a great river there goes by the name of *Alaghschak*. Besides, it is unquestionable, that Bering, as well as Tschirikow, actually reached this great continent; for, at Cape Elie, where Bering moored his frigate, they saw the coast rise into a chain of mountains which were covered with thick forests. The soil was of a nature totally different from that of Kamtschatka; and Steller collected a number of American plants."

M. de Domascheneff farther observes, that all the islands of Foxes, as well as those of Aleutes and Bering, are mountainous; that their coasts are rocky, often terminate in precipices, and are surrounded to a considerable distance with rocks; that the country rises, from the coasts to the middle of these islands, into rugged mountains, which form small chains through the whole length of each island. Besides, there have been, and still are, volcanos in several of these islands; and in those where the volcanos are extinguished, there are fountains of hot water. In the islands with the volcanos, no metals are found, but only calcedons, and some other coloured stones of no value. In these islands, the inhabitants have no other wood but what is floated in to them by the sea, and the quantity is not great. More wood arrives in the island of

Bering and the Aleutes. This floated wood seems to come from the south; for the camphor tree of Japan has been found on the coasts of these islands.

The inhabitants are pretty numerous; but, as they lead a wandering life, and transport themselves from one island to another, it is not possible to ascertain their number. It has been remarked, in general, that the larger the islands are, the nearer they are to America, and the more populous. It likewise appears, that all the inhabitants of the islands of Foxes are of the same nation, to which those of the Aleutes and the islands of Andrien may also be referred, though they differ in some customs. All these people, in their manners, modes of living, and of feeding, have a great resemblance to the Esquimaux and the Greenlanders. *Kanaghist*, the name of these islanders in their own language, and perhaps corrupted by the mariners, has still a great affinity to *Karalit*, the denomination of the Esquimaux and their brethren the Greenlanders. Among the inhabitants of all the islands between Asia and America, no other utensils were found but stone hatchets, flint knives, and the shoulder bones of animals sharpened to cut herbage. They have likewise darts armed with sharp flints, and most artfully cut. They have now a great many implements of iron, which they have obtained from the Russians. They make canoes like the Esquimaux; some of them are so large that they contain twenty persons.

They are made of light wood, and are entirely covered with the skins of seals and other sea animals.

From all these facts, it appears, that, from time immemorial, the Tschutschis, who inhabit the eastern point of Asia between the fifty-fifth and seventieth degree of latitude, have had commerce with the Americans; that this intercourse was the more easy to a people accustomed to all the rigours of cold; and that the voyage, which perhaps exceeds not a hundred leagues, might be performed in simple canoes, conducted by oars in summer, and probably on the ice in winter, by landing daily upon a different island. America, therefore, might be peopled by Asia under this parallel; and every circumstance seems to indicate, that, though there are now intervals of sea between these islands, they formerly constituted but one continent, by which America was joined to Asia. It is likewise probable, that, beyond the islands of Anadir or Andrien, *i. e.* between the seventieth and seventy-fifth degree of latitude, the two continents are absolutely united, though that track of land is perhaps entirely covered with snow and ice. To explore the regions beyond the seventieth degree is an enterprise worthy of the great sovereign of the Russias, and it ought to be entrusted to a navigator equally intrepid as captain Phipps. I am persuaded, that they would find the two continents united; but, if otherwise, and if there is an open sea beyond the islands of Andrien, it appears to be certain, that they would find the

projections of the great polar glacier at the eighty-first or eighty-second degree, as captain Phipps discovered them at the same latitude between Spitzbergen and Greenland.

Concerning that Period when the Powers of Man aided those of Nature.

The first men were witnesses of the convulsive motions of the earth, which were then frequent and terrible. For a refuge against inundations, they had nothing but the mountains, which they were often forced to abandon by the fire of volcanos. They trembled on ground which trembled under their feet. Naked in mind as well as in body, exposed to the injuries of every element, victims to the rapacity of ferocious animals, which they were unable to combat, penetrated with the common sentiment of terror, and pressed by necessity, they must have quickly associated, at first to protect themselves by their numbers, and then to afford mutual aid to each other in forming habitations and weapons of defence. They began with sharpening into the figure of axes those hard flints, those *thunder-stones*, which their descendants imagined to have been produced by thunder, and to have fallen from the clouds, but which, in reality, are the first monuments of human art. They would soon extract fire from these flints by striking them against each other.

To destroy the brushwood and the forests,

they would employ the flames derived from volcanos, or from their burning lavas; for, with the assistance of this powerful element, they cleared and purified the grounds which they chose to inhabit. With the axes of stone, they cut trees, and fabricated those weapons and utensils of which necessity first suggested the use; and, after being provided with clubs and other heavy armour, would not these first men discover the means of making lighter weapons to annoy at a distance? The tendon of an animal, the fibres of aloes, or the pliant bark of some ligneous plant, would serve them for a cord to unite the extremities of an elastic branch; with which they made their bow: to arm their arrows, they employed small sharp flints. In a short time they would have thread, rafts, and canoes; and in this state they would remain till little nations were formed. These nations were composed of a few families, or rather of the descendants of the same family, which is still the condition of those savages who live independent in such open and spacious territories as afford them game, fishes, and fruits. But, in territories which are narrowed by waters, or confined by high mountains, these small nations, after a great increase of population, were obliged to divide the land among themselves; and, from this moment, the earth became the inheritance of man. He took possession of it by his labour and cultivation; and the attachment to a native soil followed rapidly the first acts of property. As indi-

vidual interest constitutes a part of national order, government and laws must have succeeded, and society must have assumed strength and consistence.

Nevertheless, these men, deeply affected with the miseries of their original state, and having still before their eyes the ravages of inundations, the conflagrations of volcanos, and gulfs opened by the succussions of the earth, have preserved a durable, and almost eternal remembrance of the calamities the world has suffered. The idea, that it must perish by an universal deluge, or by a general conflagration; the reverence for certain mountains, upon which they had been saved from inundations; their horror at others, which threw out fires more dreadful than those of thunder; the view of those combats between the earth and heavens, which gave rise to the fable of the Titans, and of their assaults against the gods; the notion of the real existence of a malevolent being, with the terror and superstition which it unavoidably produced: all these sentiments, founded upon fear, took an unconquerable possession of the human mind. Even at present, men are not entirely emancipated from these superstitious terrors by the experience of time, by the tranquillity which succeeded those ages of convulsions and storms, nor by the knowledge of the effects and operations of Nature, a knowledge which could not be acquired till after the establishment of some great society in a tranquil land.

It is neither in Africa nor in the most south-

ern regions of Asia; that great societies or nations could be first formed. These countries were still burning and desert. Neither could this event happen in America, which, except its chain of mountains, is evidently a new country; nor even in Europe, which very lately derived its learning from the East, where the first civilized men were established; for, before the foundation of Rome, the happiest countries in this part of the world, such as Italy, France, and Germany, were then peopled with men more than half savage. Tacitus, in his Manners of the Germans, exhibits a picture of those of the Hurons, or rather of men just emerging from a state of nature. Hence the source of human knowledge must have arisen in the northern countries of Asia; and power is a necessary result of knowledge. The more man knows, the more he can perform; and the less he has done, the less he knows. All this implies an active people in a happy climate, living under a pure sky and in a fertile country, remote from inundations and volcanos: it must also have been a high country, and, of course, more anciently temperate than the more southern regions. Now, all these conditions, all these circumstances, are united in the centre of Asia, from the fortieth to the fifty-fifth degree of latitude. The rivers which run into the North Sea, into the Eastern Ocean, and into the South and Caspian Seas, take their rise from this elevated region, which at present composes the southern part of Siberia and of Tartary. It is, therefore, in this country, which is more

elevated than all the others, since it serves them as a centre, and is near 500 leagues from any ocean; it is in this privileged country that the first people worthy of notice were produced; and they merit our esteem as the inventors of arts, sciences, and every useful institution. This truth is equally evident from the monuments of natural history, and from the almost inconceivable progress of astronomy. How could men so new invent the lunisolar period of 600 years? I confine myself to this single fact, though many others, equally wonderful and permanent, might be produced. These people, therefore, knew as much of astronomy as was known in the days of Cassini, who first demonstrated the reality and exactness of this period of 600 years; a knowledge of which the Chaldeans, Egyptians, and Greeks, were perfectly ignorant; a knowledge which presupposes that of the exact movements of the earth and moon, and requires great perfection in the instruments necessary to make observations; a knowledge which, as it implies the acquisition of every thing derived from a long succession of astronomical study and research, must have required at least two or three thousand years' exertion of the human mind.

These first people, because they had become very learned, must have been proportionally happy. They must have enjoyed many ages of peace and leisure, which are necessary for the cultivation of science. Before they could entertain a suspicion concerning the period of 600 years, at least 1,200 years of astronomical obser-

vations were requisite; and, to ascertain the fact, more than double that number of years were necessary. Thus we have already about 3,000 years employed in astronomical studies; neither should this circumstance surprise us; for, in reckoning from the Chaldean astronomers to the present day, an equal time has been employed in discovering this period of 600 years. Besides, these 3,000 years of astronomical observations must necessarily have been preceded by many ages in which science was unknown. Nay, are 6,000 years from the present time sufficient to discover the most noble epoch in the history of man, or even to trace his gradual progress in the arts and sciences?

But, unhappily, these sublime and beautiful sciences are lost; we can only recognise their past existence by deformed and imperfect fragments. The invention of the *formula* by which the Brahmins calculate eclipses, presupposes as much science as the construction of our ephemerides; and yet these Brahmins have not the smallest idea of the structure of the universe. They possess only some false notions concerning the motion, magnitude, and position of the planets. They calculate eclipses without knowing the theory of them. This operation they are enabled to perform by machines or tables founded upon learned formulæ, which they do not comprehend, and which, probably, were not invented by their ancestors; because they have never brought any thing to perfection, and have not transmitted the smallest ray of science to

their descendants. In their hands, these formulæ are only practical methods; but they imply profound knowledge, of which these people have not preserved the slightest vestige, and which, of course, they have never possessed. Hence these methods could only proceed from that ancient people, who had reduced into formulæ the motion of the stars, and who, by a long course of observations, could not only predict eclipses, but, what is much more difficult, they recognised the period of 600 years, and, of course, were acquainted with all those astronomical facts which this discovery necessarily required.

I may affirm, that the Brahmins never invented these formulæ; because all their physical ideas are contrary to the theory on which their formulæ depend. If they had comprehended this theory, even at the time they received its results, the science would have been preserved, and they would not, as they do at present, have entertained the most absurd and ignorant notions concerning the system of the universe; for they believe that the earth is immoveable, and is supported by a mountain of gold; that the moon is eclipsed by aërial dragons; that the planets are smaller than the moon, &c. It is therefore evident, that they never had the first elements of astronomical theory, nor the smallest knowledge of the principles upon which the methods they employ depend*.

* For a more complete view of this subject, I refer the reader to an excellent account of ancient astronomy lately published by Bailly, whose ideas perfectly coincide with mine.

The Chinese, who are a little more enlightened than the Brahmins, calculate eclipses in a very rude manner, and they have continued to calculate them in the same manner for 2,000 or 3,000 years. As they bring nothing to perfection, they can never invent. Hence science neither originated in China nor in India. Though equally near as the Indians to the first learned people, the Chinese appear not to have derived any advantage from this favourable situation. They are not even possessed of those astronomical formulæ of which the Brahmins have preserved the use, and which constitute the first great monuments of the knowledge and happiness of man. Neither does it appear that the Chaldeans, Persians, Egyptians, or Greeks, received any advantage from this first enlightened race of men; for, in these Levant countries, the new astronomy must be ascribed to the indefatigable assiduity of the Chaldean observers, and afterwards to the labour of the Greeks, which can only be dated from the foundation of the Alexandrian school. This science, however, after the culture of 2,000 years, and even till these two or three last centuries, was very imperfect. It seems, therefore, to be certain, that these people, who first invented, and for a long succession of ages so happily cultivated astronomy, have left nothing but some fragments, some results of the science, which might be retained in the memory, such as that of the period of 600 years, which has been transmitted to us by Jo-

sephus, the Jewish historian, who did not understand its value or import.

The loss of the sciences, that first wound to humanity, inflicted by the sword of barbarity, must have been the effect of some direful revolution, which, in a few years perhaps, destroyed the labours and ingenuity of many ages; for those first powerful and learned people must have continued long in a state of splendor and prosperity, since they made so great progress in the sciences, and, of course, in all the arts which the study of them necessarily requires. But it is extremely probable, that, when the regions to the north of this happy country had become too cold, their inhabitants, still ignorant, ferocious, and barbarous, would pour in upon this rich and cultivated country. It is even astonishing, that these barbarians should have been able to annihilate not only the principles, but the remembrance of all science. Three thousand years of ignorance, perhaps, followed the three thousand years of light and knowledge which had preceded them. Of all these first and beautiful fruits of the human genius, there now remains nothing but a metaphysical religion, which, being incomprehensible, required no study, and could neither be altered nor lost, but by a defect of memory, which never fails when it is struck with the marvellous. From this first centre of the sciences, the same metaphysical religion diffused itself over every quarter of the globe. The idols of Calicut are the same with those of Selegin-

skoi. Pilgrimages to the great Lama are undertaken at the distance of more than 2,000 leagues. The idea of the metempsychosis, or transmigration of souls, extends still farther, and is adopted as an article of faith by the Indians, the Æthiopians, and the Atlantes. The same notions, a little disguised, were received by the Chinese, Persians, Greeks, and Romans. Every circumstance concurs in proving, that the first common stem of human knowledge arose in this region of Asia *, and that its barren or degenerated branches extended into every part of the earth.

The past ages of barbarity are for ever buried in profound darkness. Men were then so deformed with ignorance, that human nature was hardly recognisable: for rudeness, followed by the neglect of duty, began to relax the bonds of society; which were afterwards torn asunder by barbarity; the laws were despised or proscribed; manners degenerated into habits of ferocity; the love of society, though engraven on the human heart, was totally effaced; in a word, man, without education, without morals, was reduced to lead a solitary and savage life, and, instead

* The learned M. Pallas remarks, that the cultivation, the arts, and the towns thinly scattered through this region, are living monuments of an empire or flourishing society, whose history is buried with its cities, temples, and arms, of which enormous ruins are daily dug out of the earth. These scattered people are the members of a great nation, which has no head. Voyage de Pallas en Siberie.

of the high dignity of his nature, presented the picture of a being degraded below the brutes.

However, after the loss of the sciences, the useful arts to which they had given birth were preserved. The cultivation of the earth, which became more necessary in proportion to the increase of population; all the arts and practices which this culture requires, as well as all those employed in the construction of buildings, in the fabrication of idols and arms, in the weaving of stuffs, &c., survived the sciences. These arts were gradually diffused and brought to perfection: they followed the course of population. The ancient empire of China first arose, and, nearly at the same time, that of the Atlantes in Africa. The empires on the continent of Asia, those of Egypt and Æthiopia, were successively established, and, lastly, that of Rome, to which our Europe owes its civil existence. Hence, about 3,000 years only have elapsed since the power of man united with that of Nature, and spread over the greatest part of the earth. Before this period, the treasures of fertility were buried. The other resources of man, still more profoundly interred, could not elude his researches, but have become the reward of his labours. When he conducted himself with wisdom, he followed the lessons of Nature; he derived advantage from her examples; he employed her means, and, from the immensity of her productions, selected all those objects from which he could derive either utility or pleasure.

By his intelligence, the animals were subdued, tamed, and reduced to perpetual slavery. By his labours, the marshes were drained, the rivers were restrained, and their cataracts effaced, the forests were cleared, and the earth cultivated. By his reflection, times were computed, spaces were measured, the celestial motions were recognised, combined, and represented, the heavens and the earth were compared, the universe was augmented, and the Creator worthily adored. By his art, which is an emanation of science, the seas have been traversed, and the mountains overcome; nations have been united; a new world has been discovered; a thousand other detached lands have been reduced under his dominion; lastly, the whole face of the earth at present exhibits the marks of his power, which, though subordinate to that of Nature, often exceeds, at least so wonderfully seconds her operations, that, by the aid of his hands, her whole extent is unfolded, and she has gradually arrived at that point of perfection and magnificence in which we now behold her.

Compare rude with cultivated Nature. Compare the small savage nations of America with those of our civilized people, or even with those of Africa, who are only half cultivated. Contemplate the condition of the lands which those nations inhabit, and you will easily perceive the insignificance of men who have made so little impression on their native soil. Whether from stupidity or indolence, these brutish men, these unpolished nations, great or small,

give no support to the earth; they starve without fertilizing her; they devour every thing, and propagate nothing. The savage state, however, is not the most despicable condition of mankind, but that of those nations who have just begun to be polished, who have always been the real scourges of human nature, and who, even at present, can hardly be restrained by the people who are completely civilized. They have, as formerly remarked, ravaged the first happy land. They have torn up the germs of happiness, and destroyed the fruits of science. How many invasions have succeeded the first irruptions of barbarians? From these same northern regions, where every human virtue formerly existed, all our evils afterwards proceeded. How often have we seen these irruptions of animals with human faces, who always come from the north, ravage the countries of the south? Consult the annals of all nations, and you will find twenty ages of desolation for a few years of ease and tranquillity.

Nature required 600 ages to construct her great works, to temper the earth, to fashion its surface, and to arrive at repose: how many ages would men require before they ceased to disturb and destroy each other? When will they learn, that the peaceable possession of their own country is sufficient for their happiness? When will they be wise enough to give up their false pretensions, to renounce imaginary dominions, and distant possessions, which are often ruinous; or at least cost more than their value? The Spa-

nish empire in Europe is as extensive as that of France, and ten times larger in America: is it ten times more powerful? Is it even as powerful as if this bold and great nation were limited to derive from its own happy country all the benefits which it could furnish? Have not the British, a people so sensible, and such profound thinkers, committed a great error by extending too far the limits of their colonies? The ancients appear to have had more correct ideas with regard to these establishments. They never projected emigrations till their population was too great; and their territory and commerce were not sufficient to supply their wants. Have not the invasions of barbarians, which we look upon with horror, had causes still more pressing, when they found themselves too numerous in ungrateful, cold, and naked countries, and at the same time surrounded with fertile and cultivated lands, which produced every article they required? But, what quantities of blood, what calamities, what losses, have accompanied and followed these direful conquests?

We shall dwell no longer on the dismal spectacle of those revolutions of death and devastation, which are the genuine effects of ignorance. Let us entertain the agreeable hopes, that the balance, though imperfect, which subsists between cultivated nations, will continue, and become even more stable in proportion as men shall have better notions of their real interest; that they will learn the value of peace and tranquil happiness; that the acquisition of this object

will be the chief aim of their ambition; and that princes will disdain the false glory of conquerors, and despise the little restless vanity of those who excite them to such dreadful commotions.

Let us suppose the world in peace, and take a nearer prospect of the influence of man's power over that of Nature. Nothing appears to be more difficult, not to say impossible, than to oppose the successive cooling of the earth, and to warm the temperature of a climate; yet this feat man can and has performed. Paris and Quebec are nearly under the same degree of latitude; Paris, therefore, would be as cold as Quebec, if France and the adjacent countries were as thinly inhabited, and as much covered with wood and water as the territories in the neighbourhood of Canada. The draining, clearing, and peopling a country, will give it a warmth which will continue for some thousand years; and this fact will prevent the only reasonable objection which can be made against my opinion, that the earth is gradually cooling.

According to your system, it may be said, the whole earth must be cooler now than it was 2,000 years ago: but tradition proves the contrary. France and Germany formerly produced rein-deer, lynxes, bears, and other animals, which have since retired to more northerly regions. This progress is very different from what you maintain, namely, from north to south. Besides, history informs us, that the river Seine was annually frozen during a part

of the winter. Are not these facts a direct contradiction to the gradual cooling of the earth? They would, I acknowledge, if France and Germany were now in the same state; if we had not cut down the forests, drained the marshes, confined the torrents, directed the rivers, and cleared all the lands which were overgrown with unprofitable plants. But we ought to consider that the heat of the globe diminishes in an imperceptible manner; that 72,000 years were necessary to cool it to a proper temperature, and that an equal portion of time must elapse before it is so cold as to be unfit for the nourishment of animals and vegetables. We must consider the difference between this slow cooling of the earth and the sudden colds produced in the atmosphere; and we must nevertheless recollect, that the difference between the greatest heat of our summers and the greatest cold of our winters exceeds not a thirty-second part. From these considerations it is apparent, that external causes have a much greater influence upon the temperature of every climate than the internal cause, and that, in all those climates where the cold of the superior regions of the air is attracted by moisture, or pushed by the winds towards the surface, the effects of these particular causes are much more powerful than that produced by the general cause. Of this we shall give an example, which will remove every doubt, and at the same time obviate every similar objection:

In the immense territories of Guiana, which are covered with thick forests, where the sun

can hardly penetrate, where great tracts of country are overflowed with water, where the rivers are very near each other, and are neither restrained nor directed, where it rains continually during eight months of the year, the inhabitants, about a century ago, began to clear the country around Cayenne, which is a very small canton, of these vast forests. The difference of temperature in this little district is already so perceptible, that the people are too warm during the night; but, in all the lands which are covered with wood, the nights are so cold, that fires are necessary in the houses. The same effect is produced with regard to the quantity and duration of the rains: they cease sooner and commence later at Cayenne than in the interior parts of the country; neither are they so heavy, nor so frequent. At Cayenne, there are four months of absolute dryness: but in the interior parts of the country, the dry season lasts only three months; besides, a daily rain is brought down by the south winds, which is pretty violent. Another circumstance merits attention: it seldom thunders at Cayenne; but, in the interior parts, where the clouds are black, thick, and very low, the thunder is violent and very frequent. These facts show, in the clearest manner, that, in this country, the eight months of perpetual rain might be diminished, and the heat greatly augmented, if the forests were cut down, if the waters were restrained, and the rivers properly directed, and if the cultivation of the earth, which supposes the movements of a great number of men

and animals, banished that cold and superfluous moisture which is attracted and diffused by the immense quantity of vegetables.

As every action, every movement, produces heat, and as all beings endowed with the faculty of progressive motion may be considered as so many little fires, it is in proportion to the number of men and animals, that (every thing else being equal) the local temperature of each particular country depends. The former diffuse heat, the latter nothing but cold and moisture. The perpetual use men make of fire adds greatly to the artificial temperature of all populous territories. In Paris, during great colds, the thermometers at the Faubourg Saint Honoré stand two or three degrees lower than those at the Faubourg Saint Merceau; because the north wind is heated in passing over the numerous chimneys of that great city. A single forest in any country is sufficient to produce some change in its temperature. Trees, by their shade, diminish the heat of the sun; they produce moist vapours, that form clouds, and fall down in rain, which is always colder from the greater height it descends. When these forests are abandoned to Nature alone, the old trees fall and coldly corrupt; but, when under the dominion of man, they are used as fuel to the element of fire, and become the secondary causes of every particular heat. In meadows, before the herbage is cut down, there are always copious dews, and often small showers of rain, which cease as soon as the grass is carried off. These

small rains would become more abundant and more durable, if our meadows, like the savannahs of America, were always covered with the same quantity of herbs, which, instead of diminishing, must increase by the accumulating manure of all those that die and corrupt on the surface.

Many other examples might be given, all concurring to show that man can have an influence on the climate he inhabits, and, in a manner, fix its temperature at any point that may be agreeable to him; and, what is singular, it is more difficult for him to cool than to heat the earth. He is master of the element of fire, which he can augment and propagate at pleasure, but not of the element of cold, which he can neither lay hold of nor communicate. The principle of cold is not a real substance, but a simple privation, or rather diminution of heat; a diminution which ought to be very great in the high regions of the air, and which, at the distance of a league from the earth, converts the aqueous vapours into hail and snow. For the emanations of the heat proper to the globe observe the same law as all other physical quantities or qualities which proceed from a common centre; and, as their intensity decreases in the inverse ratio of the square of the distance, it appears to be certain, that the atmosphere is four times colder at the height of two leagues than at that of one, each point of the earth's surface being considered as a centre. On the other hand, the interior heat of the globe, in every

season, is constantly ten degrees above the freezing point. Hence the earth can never be colder than ten degrees above this point, except by the fall of cold matters upon its surface from the superior regions of the air, where the effects of the internal heat of the globe diminish in proportion to the height. Now, the power of man extends not so far. He cannot make cold descend, as he makes heat ascend. He has no other mode of defending himself from the ardour of the sun's rays, but by forming a shade. But it is more easy to cut down the forests of Guiana, in order to heat the humid earth, than to plant trees in Arabia to refresh the burning sands. A single forest, however, in the midst of these parched deserts, would be sufficient to render them more temperate, to attract the waters from the atmosphere, to restore all the principles of fertility to the earth, and, of course, to make man, in these barren regions, enjoy all the sweets of a temperate climate.

It is upon the difference of temperature that the stronger or weaker energies of Nature depend. The growth, and even the production, of all organized beings, are only particular effects of this general cause: hence man, by modifying this cause, may in time destroy what injures him, and give birth to every thing that is agreeable to his feelings. Happy are those countries where all the elements of temperature are balanced, and so fortunately combined as to produce only good effects! But, has any country, from its origin, ever enjoyed this privilege? Is

there any country where the power of man has not aided that of Nature, either by attracting or dissipating the waters, by destroying noxious or superfluous vegetables, and by taming and multiplying useful animals? Of 300 species of quadrupeds, and 1,500 species of birds, man has selected nineteen or twenty*; and these twenty species make a greater figure in Nature, and are more useful to the earth than all the others: they make a greater figure, because they are directed and prodigiously multiplied by man. By cooperating with him, they produce all the benefits which could be expected from a wise distribution of powers in cultivating the earth, in transporting the articles of commerce, in augmenting provisions, in supplying all the wants, and in ministering to the pleasures of their only master, who can reward their services by his industry and attention.

Of the small number of animals selected by man, the hen and the hog species, which are the most prolific, are likewise the most generally diffused, as if the aptitude for great multiplication were accompanied with that vigour of constitution, which braves every danger or inconveniency arising from difference of climate. The hen and the hog have been found in the most unfrequented regions of the earth, in Otaheite and other southern islands, which are the most

* The elephant, the camel, the horse, the ass, the ox, the sheep, the goat, the hog, the dog, the cat, the lama, the *vigogne*, *the buffalo*, *the hen*, *the swan*, *the guiney-hen*, the duck, the peacock, the pheasant, and pigeon.

remote from any continent, and have, till very lately, remained unknown. It appears that these species have followed man in all his emigrations. In South America, where none of our animals could possibly arrive, we find the pecari and wild hen, which, though smaller and a little different from the hog and hen of our continent, must be regarded as a species so much allied that they might easily be reduced to a domestic state. But savage man, having no idea of society, is not solicitous about that of animals. In the regions of South America, the savages have no domestic animals. They destroy indifferently the good with the bad species. They select none for the purposes of rearing and multiplying them; while a single fertile species, like that of the *hocco**, which is at their command, would furnish them, with very little attention, more subsistence than they can procure by their laborious and painful huntings.

Thus the first mark of man's civilization is the empire he assumes over the animals; and this first mark of his intelligence becomes afterwards the greatest evidence of his power over Nature: for it is only after he subjugates and tames animals, that he is enabled, by their assistance, to change the face of the earth, to convert deserts into fertile ground, and heath into corn. By multiplying useful animals, he augments the quantity of life and motion on the surface of the

* A large and very prolific bird, whose flesh is as good as that of the pheasant.

earth; he, at the same time, improves the whole race of beings, and ennobles himself, by transforming the vegetable into the animal, and both into his own substance, which afterwards diffuses itself by a numerous multiplication. He every where produces plenty of provisions, which is always succeeded by great population. Millions of men exist in the same space which was formerly occupied by 200 or 300 savages, and millions of animals where only a few individuals existed. By him, and for his use, all the precious germs are unfolded; the productions of the noblest kinds are alone cultivated; upon the immense tree of fecundity the fruitful branches are alone brought to perfection.

Grain, of which man makes bread, is not the gift of Nature, but the fruit of his researches and of his knowledge in the first of all arts. In no quarter of the earth has wild corn been ever found: it is evidently an herb brought to perfection by his care and industry*. This precious plant he must have selected out of many thousands. He must have sown and reaped a number of times, in order to discover its fertility, which is always proportioned to the manure and culture bestowed upon the soil: and the singular quality possessed by wheat of resisting, in its early state, the cold of our winters, though, like all other annual plants, it perishes

* Man is indebted to Nature for his ability to cultivate the earth. Grain is produced by cultivation, consequently grain is the gift of Nature. W.

after yielding its seed, and its no less wonderful qualities of being nutritious and agreeable to all men, to many animals, accommodated to almost every climate, and can be long preserved without corruption, and without losing its power of reproduction; all these circumstances concur in proving that it is the most happy invention ever discovered by man; and, however ancient it may be supposed, it must have been preceded by the art of agriculture founded upon science, and brought to perfection by experience and observation.

If more modern and even recent examples of man's power over the nature of vegetables are required, we have only to compare our pot-herbs, our flowers, and our fruits, with those of the same species as they existed fifty years ago. This comparison may be instantly made, by inspecting the great collection of flowers, which was begun in the time of Gaston d'Orleans, and continued to this day, in the Royal Garden. We shall then perceive, perhaps with surprise, that the most beautiful flowers of that period, as the ranuncili, pinks, tulips, auricula, &c., would now be rejected, not by florists alone, but by the most vulgar gardeners. These flowers, though then cultivated, were not far removed from their natural state. A single row of petals or flower leaves, long stamina, and hard or disagreeable colours, without variety, and without delicate shades, are the rustic characters of savage nature. Our pot-herbs consisted of a single species of succory, and two of lettuce, both very

bad; but we have now more than fifty kinds of lettuce and succory, all of which are good. Our best fruits and nuts, which are so different from those formerly cultivated, that they have no resemblance but in the name, must likewise be referred to a very modern date. In general, substances remain, and names change with times. But, in this case, names remain, and substances are changed. Our peaches, our apricots, our pears, are new productions with ancient names. To remove every doubt upon this subject, we have only to compare our flowers and fruits with the descriptions, or rather notices of them, transmitted to us by the Greeks and Romans. All their flowers were single, and all their fruit trees were wild stocks, and their species very ill chosen: their fruits, of course, were small, dry, sour, and had neither the flavour nor the beauty of ours.

These new and good species originally sprung from the wild kinds; but, how many thousand times have their seeds been sown before this happy effect was produced? It was only by sowing and rearing an infinite number of vegetables of the same species, that some individuals were recognised to bear better and more succulent fruit than others; and this first discovery, which supposes much care and observation, would have remained for ever useless, if a second had not been made, which implies an equal degree of genius as the first required of patience; I mean the mode of multiplying by engrafting those precious individuals, which unfortunately cannot

propagate, or transmit their excellent qualities to their posterity. This fact alone shows that these qualities are purely individual, and not specific; for the seeds of these excellent fruits, like the inferior kinds, produce nothing but wild stocks, which are essentially different.

By means of engrafting, however, man has in a manner created secondary species, which he can multiply at pleasure. The bud or small branch, when united to the wild stock, retains that individual quality which it could not transmit by its seed; and, in order to produce the same fruit as its original parent, it requires only to be developed. The fruits receive none of the bad qualities of the wild stock; because it has not contributed to their formation: it is not their mother, but their nurse, which only assists their growth by conveying nourishment to them.

In the animal kingdom, most of those qualities which appear to be individual, are propagated and transmitted in the same manner as their specific qualities. It was, therefore, more easy for man to have influence upon the nature of animals than upon that of vegetables. Particular races in any species of animals are only constant varieties, which are perpetuated by generation. But, in the vegetable kingdom, there are no races, no varieties so constant, as to be perpetuated by reproduction. In the species of the hen and pigeon, a great number of races have been very lately produced, all of which propagate their kinds. In other species, we daily rear and improve races by crossing the breeds. From time

to time, we naturalize and tame foreign or wild species. All these recent examples show, that it was long before man knew the greatness of his power, and that he is not yet fully acquainted with its extent: it depends entirely on the exercise of his intellect. Thus, the more he shall observe and cultivate Nature, the more expedients he will discover for making her submit, and for drawing from her bosom fresh sources of riches, without diminishing the inexhaustible treasures of her fertility.

What influence might not man acquire over his own species, if his inclinations were always directed by his intelligence? Who knows to what degree he might improve his moral as well as his physical nature? Is there a single nation who can boast of having arrived at the best of possible governments, a government which would render all men not equally happy, but less unequally miserable, by attending to their preservation, by softening their labours, and sparing their blood by cultivating peace and procuring abundance of provisions: this is the moral end of every society of men who are anxious to improve their condition: and, with regard to the physical part of our nature, have the medical and other arts, whose objects are health and preservation, made an equal progress as the arts of destruction invented for the purposes of war and carnage? In all ages, it appears that man has reflected deeper, and made more researches, concerning evil than good. In every society there is a mixture of both; and as, of all senti-

ments which affect the multitude, fear is the most powerful, great talents in the art of doing mischief were the first which struck the mind of man; he was afterwards occupied with the arts of amusement; and it was not till after long experience in these two means of false honour and unprofitable pleasure, that he at last recognised his true glory to be science, and his true happiness peace.

GENERAL HISTORY

OF

ANIMALS.

CHAPTER I.

Analogies between Animals and Vegetables.

AMONG the numberless objects with which the surface of this globe is covered and peopled, animals hold the first rank, both on account of the relation they bear to man, and of their acknowledged superiority over vegetable and inanimated matter. The senses, the figure, and the motions of animals, bestow on them a more extensive connexion with surrounding objects than is possessed by vegetables. The latter, however, from their expansion, their growth, and the variety of parts of which they are composed, are more intimately related to external objects than minerals or stones, which are perfectly inert, and deprived of every vital or active principle. It is this number of relations alone which renders the animal superior to the vegetable, and the vegeta-

ble to the mineral. Man, if we estimate him by his material part alone, is superior to the brute creation only from the number of peculiar relations he enjoys by means of his hand and of his tongue; and, though all the operations of the Omnipotent are in themselves equally perfect, the animated being, according to our mode of perception, is the most complete; and man is the most finished and perfect animal.

What a variety of springs, of powers, and of mechanical movements, are included in that small portion of matter, of which the body of an animal is composed! What a number of relations, what harmony, what correspondence, among the different parts! How many combinations, arrangements, causes, effects, and principles, all conspiring to accomplish the same design! Of these we know nothing but by their results, which are so difficult to comprehend, that they cease only to be miraculous from our habits of inattention and our want of reflection.

But, however admirable this work may appear, the greatest miracle is not exhibited in the individual. It is in the successive renovation, and in the continued duration of the species, that Nature assumes an aspect altogether inconceivable and astonishing. This faculty of reproduction *, which is peculiar to animals and vegeta-

* This word is frequently used by the author, and requires to be explained. It signifies the power of producing or propagating in general, and is equally applicable to plants and to animals. Generation is a species of reproduction peculiar to animated beings.

bles; this species of unity, which always subsists, and seems to be eternal; this generative power, which is perpetually in action, must, with regard to us, continue to be a mystery so profound, that we shall probably never reach its bottom.

Even inanimated bodies, the stones or the dust under our feet, have some properties; their very existence presupposes a great number; and matter, the most imperfectly organized, possesses many relations with the other parts of the universe. We will not assert, as some philosophers have done, that matter, under whatever form it appears, is conscious of its existence and of its relative powers. This question belongs to metaphysics, of which we intend not to treat. We shall only remark, that, being ignorant of the extent of our own connexions with external objects, we cannot hesitate in pronouncing inanimated matter to be infinitely more ignorant. Besides, as our sensations have not the most distant resemblance to the causes which produce them, analogy obliges us to conclude, that dead matter is neither endowed with sentiment, with sensation, nor with a consciousness of its own existence. Hence, to attribute any of these faculties to matter, would be ascribing to it the power of thinking, of acting, and of perceiving, nearly in the same manner as we ourselves think, act, and perceive; which is equally repugnant to reason and religion.

With inanimated matter, therefore, though formed of dust and clay, we have no other relations than what arise from the general properties

of bodies, such as extension, impenetrability, gravity, &c. But, as relations purely material make no internal impression on us, and as they exist entirely independent of us, they cannot be considered as any part of our being. Our existence, therefore, is an effect of organization, of life, of the soul. Matter, in this view, is not a principal, but an accessory. It is a foreign covering, united to us in a manner unknown; and its presence is noxious. Thought is the constituent principle of our being, and is perhaps totally independent of matter.

We exist, then, without knowing how; and we think, without perceiving the reason of thought. But, whatever be the mode of our being, or of our thinking, whether our sensations be real or apparent, their effects are not the less certain. The train of our ideas, though different from the objects which occasion them, gives rise to genuine affections, and produces in us relations to external objects, which we may regard as real, because they are uniform and invariable. Thus, agreeable to the nature of our being, it is impossible to doubt concerning the reality of those distinctions and resemblances which we perceive in the bodies that surround us. We may, therefore, conclude, without hesitation, that man holds the first rank in the order of nature, and that brute animals hold the second, vegetables the third, and minerals the last. Though we are unable clearly to distinguish between our animal and spiritual qualities; though brutes are endowed with the same senses, the same princi-

ples of life and motion, and perform many actions in a manner similar to those of man; yet they have not the same extent of relation to external objects; and, consequently, their resemblance to us fails in numberless particulars. We differ still more from vegetables; but we are more analogous to them than to minerals; for vegetables possess a species of animated organization; but minerals have nothing that approaches to regular organs.

Before we give the history of an animal, it is necessary to have an exact knowledge of the general order of his peculiar relations, and then to distinguish those relations which he enjoys equally with vegetables and minerals. An animal possesses nothing common to the mineral but the general properties of matter: his nature and economy, however, are perfectly different. The mineral is inactive, insensible, subject to every impulse, without organization, or the power of reproduction, a rude mass, fitted only to be trod by the feet of men and of animals. Even the most precious metals, which derive their value from the conventions of men only, are regarded in no other light by the philosopher. In the animal, the whole powers of nature are united. The principles with which he is animated are peculiar to him: he wills; he determines; he acts; he communicates, by his senses, with the most distant objects; his body is a world in miniature, a central point to which every thing in the universe is connected. These are his peculiar and invariable relations:

the faculties of growth and expansion, of reproduction and the multiplication of his species, he possesses in common with the vegetable kingdom.

Progressive motion appears to be the most distinguishing quality between an animal and a vegetable. We, indeed, know no vegetable that enjoys a loco-motive faculty. But this motion is denied to several species of animals, as oysters *, gall insects, &c. This distinction, therefore, is neither general nor essential.

Sensation more essentially distinguishes animals from vegetables. But *sensation* is a complex idea, and requires some explication; for, if sensation implied no more than motion consequent upon a stroke or impulse, the sensitive plant enjoys this power. But, if by sensation we mean the faculty of perceiving and of comparing ideas, it is uncertain whether brute animals are endowed with this faculty. If it should be allowed to dogs, elephants, &c., whose actions seem to proceed from motives similar to those by which men are actuated, it must be denied to many species of animals, particularly to those that appear not to possess the faculty of progressive motion. If the sensation of an oyster, for example, differ in degree only from that of a dog, why do we not ascribe the same sensation to vegetables, though in a degree still inferior? This distinction, therefore, between the animal

* This is not strictly true; for oysters, and even gall insects, are capable of a degree of local motion.

and vegetable, is neither sufficiently general nor decided.

A third distinction has been derived from the manner of feeding. Animals have organs of apprehension by which they lay hold of their food; they search for pasture, and have a choice in their aliment. But plants are under the necessity of receiving such nourishment as the soil affords them, without exerting any choice in the species of their food, or in the manner of acquiring it: the moisture of the earth is the only source of their nourishment. However, if we attend to the organization and action of the roots and leaves, we shall soon be convinced, that these are the external organs by which vegetables are enabled to extract their food; that the roots turn aside from a vein of bad earth, or from any obstacle which they meet with, in search of a better soil; and that they split and separate their fibres in different directions, and even change their form, in order to procure nourishment to the plant. A general distinction, therefore, between the animal and vegetable, cannot be founded on their manner of feeding.

From this investigation we are led to conclude, that there is no absolute and essential distinction between the animal and vegetable kingdoms; but that Nature proceeds by imperceptible degrees from the most perfect to the most imperfect animal, and from that to the vegetable: hence the fresh water polypus may be regarded as the last of animals, and the first of plants.

After examining the distinctions, we shall now inquire into the resemblances which take place

between animals and vegetables. The power of reproduction is common to the two kingdoms, and is an analogy both universal and essential. This mutual faculty would induce us to think that animals and vegetables are beings of the same order.

A second resemblance may be derived from the expansion of their parts, which is likewise a common property; for vegetables grow as well as animals; and, though some difference in the manner of expansion may be remarked, it is neither general nor essential; since the growth of some considerable parts of animals, as the bones, the hairs, the nails, the horns, &c., is the effect of a genuine vegetation; and the fœtus, in its first formation, may be rather said to vegetate than to live.

A third resemblance arises from the following fact: some animals are propagated in the same manner, and by the same means, as vegetables. The multiplication of the vine-fretter *(puceron)*, which is effected without copulation, is similar to that of plants by seed; and the multiplication of the polypus by cuttings resembles that of plants by slips.

We may, therefore, conclude, with more certainty, that animals and vegetables are beings of the same order, and that Nature passes from the one to the other by imperceptible degrees; since the properties in which they resemble each other are universal and essential, while those by which they are distinguished are limited and partial.

Let us next compare animals and vegetables

in different points of view; for example, with regard to number, situation, magnitude, figure, &c., from which new inductions will arise.

Animals exceed plants in the number of species. In the class of insects alone, there are, perhaps, a greater number of species, than of the whole species of plants on the face of the earth. Animals differ from each other much more than plants: it is the great similarity of plants that has given rise to the difficulty of distinguishing and arranging them, and to the variety of botanical systems, which are much more numerous than those of *zoology*.

Beside being more strongly characterised, every species of animal is distinguishable from another by copulation. Those may be regarded as of the same species which, by copulation, uniformly produce and perpetuate beings every way similar to their parents; and those which, by the same means, either produce nothing, or dissimilar beings, may be considered as of different species. A fox, for example, will be of a different species from a dog, if nothing results from the intercourse of a male and a female of these two animals; or if the result be a dissimilar creature, a kind of mule, as this mule cannot multiply, it will be a sufficient demonstration that the fox and dog are different species of animals. In plants, we have not the same advantage; for, though sexes have been attributed to them, and generic distinctions have been founded on the parts of fructification; yet, as these characteristics are neither so certain nor so ap-

parent as in animals; and as the reproduction of plants can be accomplished by several methods which have no dependence on sexes, or the parts of fructification, this opinion has not been universally received; and it is only by the misapplication of analogy, that the sexual system has been pretended to be sufficient to enable us to distinguish the different species of the vegetable kingdom.

Though the species of animals be more numerous than those of plants, the number of individuals in each species of the latter far exceed those of the former. In animals, as well as in plants, the number of individuals is much greater in the small than in the large kinds. Flies are infinitely more numerous than elephants; and there are more herbs than trees. But, if we compare the number of individuals in each species, the individuals in each species of plants far exceed those of the animal. Quadrupeds, for example, produce but few at a time, and at considerable intervals. Trees, on the contrary, produce annually an amazing number of seeds. It may be alleged, that, to render this comparison exact, the number of seeds produced by a tree should be compared with the number of germs contained in the semen of an animal; and then, perhaps, it would appear, that animals abound more in germs than vegetables. But, by collecting and sowing the seeds of a single elm tree, 100,000 young elms may be raised from the product of one year. Though a horse, however, were furnished with all the mares he could cover

in a year, the result between the production of the animal and of the plant would be very different. I avoid taking notice of the number of germs; because of these (especially in the animal) we have no certain knowledge, and because the same seminal germs may exist in the vegetable; for the seed of a plant is not a germ, but a production as perfect as the fœtus of an animal, and which, like a fœtus, requires only the expansion of its parts.

To this may be opposed the prodigious multiplication of some kinds of insects, as the bee, a single female of which will produce thirty or forty thousand. But, it ought to be remarked, that I am here speaking in general of animals compared with vegetables. Besides, the bee, which affords, perhaps, an example of the greatest multiplication among animals, proves nothing against the present doctrine; for, out of thirty or forty thousand flies produced by the mother-bee, there are but very few females, and no less than 1,500 or 2,000 males: the rest are of neither sex, and totally incapable of procreating.

It must be acknowledged, that some species of insects, fishes, and shell animals, appear to be extremely prolific. Oysters, herrings, fleas, &c., are perhaps equally fertile as mosses, and the most common plants. But, in general, most species of animals are less prolific than plants; and, upon comparing the multiplication of the different species of plants, we find not such remarkable differences, with regard to number, as take place among animals. Some animals pro-

duce great numbers, and others very few. But, in every species of plants, the quantity produced is always great.

From what we have already observed, it appears, that, both in the animal and vegetable kingdoms, the smallest and most contemptible species are the most prolific. In proportion as animals seem to be more perfect, the number of individuals decreases. Does the production of particular forms of body, necessary for the perfecting of sentiment, as those of quadrupeds, and of birds, cost Nature more expense of organic particles than the production of inferior creatures?

Let us now compare animals and vegetables with regard to situation, size, and figure. Vegetables can exist no where but on the earth. Most of them are attached to the soil by roots: some, as truffles, are entirely covered with the soil; and a few grow under water. But the whole require a connexion with the surface of the earth. Animals, on the contrary, are more generally diffused. Some inhabit the surface, and others the interior parts of the earth. Some never rise above the bottom of the ocean, and others swim in the waters. The air, the internal parts of plants, the bodies of men and of other animals, and even stones themselves, are stored with inhabitants.

By the assistance of the microscope, many new species of animals have been discovered. But, what is singular, we are not indebted to this instrument for above one or two species of plants.

The small moss, of which mouldiness consists, is perhaps the only microscopic plant that has been described. From this it would appear, that Nature has refused existence to very small plants, while she has created animalcules in the greatest profusion. But this opinion should not be adopted without examination. Plants are so similar in their structure, that it is much more difficult to distinguish them than animals. This mouldiness, which we imagine to be only a very small moss, may be a forest or a garden consisting of a multitude of different plants, though we are unable to distinguish them.

Animals and vegetables differ also with regard to size. There is a greater disproportion between the bulk of a whale and that of one of these pretended microscopic animals, than between the largest oak and the small moss mentioned above. Though bulk be only a relative attribute, it may be useful to know the limits within which Nature has confined her productions. As to largeness, plants differ but little from animals. The quantity of matter in a whale and in a large tree is nearly equal; but, as to smallness, some men have pretended to have seen animals so extremely minute, that a million of them collected in a heap would not equal the small moss on a piece of mouldy bread.

The most general and most obvious distinction between plants and animals arises from their figure. The form of animals, though infinitely various, has no resemblance to that of plants: and, though the polypi, which, like plants, can

be multiplied by cuttings, may be regarded as the link which connects the animal and vegetable kingdoms, not only from the manner of their reproduction, but still more from their figure; yet there is no danger of mistaking the one for the other. The operations of some animals resemble plants or flowers. But plants never produce any thing similar to an animal; and those wonderful insects which make corals, would never have been mistaken for flowers, if, by a foolish prejudice, coral had not been regarded as a plant. Thus the errors we may commit in comparing plants and animals, are confined to a few objects which lie on the extremities of the two kingdoms; and the farther we extend our observations, we shall be the more convinced, that the Creator has instituted no fixed limits between the animal and vegetable; that these two species of organized beings possess a greater number of common properties than of real differences; that the production of an animal requires, perhaps, a smaller exertion of Nature than the production of a vegetable; or, rather, that the production of organized bodies requires no immediate exertion at all; and, lastly, that animation, or the principle of life, instead of a metaphysical step in the scale of being, is a physical property common to all matter.

CHAP. II.

Of Reproduction in general.

WE shall now examine more closely this property, which is common to the animal and vegetable, this faculty of producing beings similar to themselves, this successive chain of individuals which constitutes the real existence of the species: and, without limiting our research to the generation of man, or of any particular animal, let us contemplate the general phænomena of reproduction; let us collect facts, and enumerate the various methods employed by Nature for the renovation and transmission of organized existences.

The first, and apparently the most simple, method, is to assemble in one body an infinite number of similar organic bodies, and to compose its substance in such a manner, that every part shall contain a germ or embryo of the same species, and which might become a whole of the same kind with that of which it constitutes a part *.

* The intelligent reader will perceive that this sentence, though not very obvious, contains the principle upon which the subsequent theory of generation adopted by the author is founded. It means no more than that the bodies of animals and of vegetables are composed of an infinite number of organic particles, perfectly similar, both in figure and substance, to the whole animal or plant, of which they are constituent parts.

This apparatus appears, at first sight, to suppose a profusion of expense. Such magnificence, however, is not uncommon in Nature. It is discernible even in the more common and inferior species, as in worms, polypi, elms, willows, and many other plants and insects, every part of which contains a whole, and, in order to become a plant or an insect, requires only to be unfolded or expanded. Considering organized bodies under this point of view, an individual is a whole, uniformly constructed in all parts, a collection of an infinite number of particles every way similar, an assemblage of germs or minute individuals of the same species, which, in certain circumstances, are capable of being expanded, and of becoming new beings, like those from which they were originally separated.

This idea, when traced to the bottom, discovers a relation between animals, vegetables, and minerals, which we would not have suspected. Salts, and some other minerals, consist of parts similar to one another, and to the whole. A grain of sea salt, as we distinctly perceive by the microscope, is a cube composed of an infinite number of smaller cubes *, which, as we dis-

* Hæ tam parvæ quam magnæ figuræ (salium) ex magno solum numero minorum particularum, quæ eandem figuram habent, sunt conflatæ, sicuti mihi sæpe licuit, observare, cum aquam marinam aut communem in qua sal commune liquatum erat, intueor per microscopium, quod ex ea prodeunt elegantes, parvæ, ac quadrangulares figuræ adeo exiguæ, ut mille earum myriades magnitudinem arenæ crassioris ne æquent. Quæ salis minutæ particulæ, quam primum oculis

cover by a larger magnifier, are themselves composed of still smaller cubes. The primitive and constituent particles of this salt must, therefore, unquestionably, consist of cubes so minute, that they will for ever escape our observation. Plants and animals, which possess the power of multiplying by all their parts, are organized bodies composed of similar organic bodies, the primitive and constituent particles of which are also organic and similar. Of these we discern the accumulated quantity; but we can only recognise the constituent particles by reason and analogy.

From this view, we are led to conclude, that there exists in nature an infinity of *organic living particles* *, of the same substance with organized beings. A similar structure we have already remarked in more inanimated matter, which is composed of an infinite number of minute particles that have an exact resemblance to the whole body. And as the accumulation perhaps of millions of cubes is necessary to the formation of a single grain of sea salt that is per-

conspicio, magnitudine ab omnibus lateribus crescunt, suam tamen elegantem superficiem quadrangularem retinentes, fere. . . . . . Figuræ hæ salinæ cavitate donatæ sunt, &c. See Leeuwenhoek, Arc. Nat. tom. i. p. 3.

* To avoid the introduction of terms which might not be generally understood, it is necessary to inform the reader, that the phrases *corps organiques vivans, parties organiques vivantes,* et *molecules organiques vivantes,* which occur so often in this volume, and form the basis of our author's theory, are uniformly, in the version, expressed by the words *organic particles.*

ceptible by our senses, an equal number of similar organic particles is requisite to produce one of those numberless germs contained in an elm, or in a polypus. A cube of sea salt must be dissolved before we can discover, by means of crystallization, the minute cubes of which it is composed: in the same manner, the parts of an elm or of a polypus must be separated, before we can recognise, by means of vegetation or expansion, the small elms or polypi contained in the different parts of these bodies.

The difficulty of assenting to this idea proceeds from the well known prejudice, that we can only judge of the compound by the simple; that, to discover the organic structure of any being, it must first be reduced to its simple and unorganic parts; and that hence it is more easy to conceive how a cube must necessarily be composed of other cubes, than how a polypus can be composed of other polypi. But, if we examine attentively what is meant by simple and compound, we shall find, that in this, as in every thing else, the plan of Nature is very different from the grossness and imperfection of our conceptions.

Our senses, it is well known, convey not to us exact representations of external objects. When we want to calculate, to judge, to compare, to weigh, to measure, &c., we are obliged to have recourse to foreign aid, to rules, to principles, to usages, to instruments, &c. All these aids are efforts of human genius, and belong more or less to the abstraction of our ideas. This abstraction, with regard to us, constitutes

the simplicity of things; and the difficulty of reducing them to this abstraction is the compound. Extension, for example, being a general and abstract property of matter, is not much compounded. In order, however, to judge concerning it, we have imagined some extensions to have no thickness, others to have neither thickness nor breadth; and points, which are extensions without being extended. All these abstractions have been invented as supports to the understanding; and the few definitions employed in geometry have given rise to numberless prejudices and false conceptions. Whatever is reducible under any of these definitions is called simple; and such things as cannot be easily reduced to this standard are considered as complex. Thus, a triangle, a square, a circle, a cube, and also those curves of which we know the geometrical properties, are regarded as simple. But every thing which we cannot reduce under these figures, or abstract rules, appears to us to be complex. We never reflect, that all these geometrical figures exist no where but in our own imaginations, or that, if they are ever found in Nature, it is only because she exhibits every possible form; and the appearance of simple figures, as an exact cube, or an equilateral pyramid, is, perhaps, more difficult and rare to be found in Nature, than the complex forms of plants or of animals. It is in this manner that we perpetually consider the abstract as simple, and the real as complex. But, in nature, no abstract exists; nothing is simple; every object is compounded.

We are unable to penetrate into the intimate structure of bodies. We cannot, therefore, determine what objects are more or less complex, unless by the greater or less relation they have to ourselves, and to the rest of the universe. For this reason we regard the animal as being more complex than the vegetable, and the vegetable than the mineral. With respect to us, this notion is just; but we know not whether the animal, vegetable, or mineral, be, in reality, the most complex or the most simple; and we are ignorant whether the production of a globe or a cube requires a greater effort of Nature than that of a germ, or an organic particle. If we were to indulge in conjectures upon this subject, we might imagine that the most common and numerous objects are the most simple. But this would make animals more simple than plants or minerals; because the former exceed the latter in number of species.

But, without dwelling longer on this subject, it is sufficient to have shown, that all our notions concerning simple and compound, are abstract ideas; that they cannot be applied to the complex operations of nature; that, when we attempt to reduce all bodies into elements of a cubical, prismatic, globular, or any other regular figure, we substitute our own imaginations in opposition to real existences; and that the forms of the constituent particles of different bodies are absolutely unknown to us; and, of course, we may believe or suppose that organized beings are composed of similar organic particles, as well

as that a cube consists of other cubes. We have no other method of judging but by experience. We know that a cube of sea salt is composed of many lesser cubes, and that an elm consists of a great number of minute elms; because if we take a piece of a branch, of a root, of the wood separated from the trunk, or a seed, from all these a new tree is produced. The polypus, and some other species of animals, may likewise be multiplied by cuttings separated from any part of their bodies; and, as our rule of judging in both cases is the same, why should we form a different opinion concerning them?

The above reasoning renders it extremely probable, that there really exists in Nature an infinite number of small organized beings, every way similar to those large organized bodies which make such a conspicuous figure in this world; that these small organized beings are composed of living organic particles, which are common both to animals and vegetables, and are their primary and incorruptible elements; that an assemblage of these particles constitutes an animal or a plant; and, consequently, that reproduction or generation is nothing but a change of form, effected solely by the addition of similar particles; and the death, or resolution of organized bodies, is only a separation of the same particles. Of the truth of this doctrine not a doubt will remain, after the proofs delivered in the following chapters are perused. Besides, if we reflect on the growth of trees, and consider what an immense mass is produced from

so small an origin, we must be persuaded that this increase of matter is effected by the simple addition of organic particles which are similar to one another and to the whole. The seed first produces a small tree, which it contained in miniature within its coats. At the top of this small tree a bud is formed, which contains the tree that is to spring the next season; and this bud is an organized body similar to the small tree of the preceding year. The small tree of the second year, in the same manner, produces a bud which contains a tree for the third year; and this process uniformly goes on as long as the tree continues to vegetate: buds are likewise formed at the extremity of each branch, which contain, in miniature, trees similar to that of the first year. It is evident, therefore, that trees are composed of minute organized bodies similar to themselves, and that the whole individual is formed by a numerous assemblage of minute and similar individuals.

But, it may be demanded, were not all these minute, and similarly organized bodies, contained in the seed? and may not the order of their unfolding be traced from that source? for it is apparent, that the first bud was surmounted by a similar bud, which was not expanded till the second year, and the third bud was not unfolded till the third year; and, consequently, the seed may be said to have really contained the whole buds which would be formed for 100 years, or till the dissolution of the plant: it is also apparent, that this seed contained not only all the

small organized bodies which must in time have constituted the individual tree itself, but likewise all the seeds, and all the individuals which would successively arise, till the final destruction of the species.

This, indeed, is a capital difficulty: we shall therefore examine it with the greater attention. It is true, that the seed produced a small tree the first year, solely by the unfolding of the bud or germ which it contained, and that this small tree existed in miniature in the bud. But it is not equally certain that the bud of the second year, and those of the succeeding years, nor that all the small organic bodies, and the seeds which must have been formed till the end of the world, or the destruction of the species, were contained in the first seed. This opinion supposes an infinite progression, and makes every individual a source of eternal generations. The first seed, for instance, must have included all the plants of its species which have existed, or ever will exist; and the first man must have contained in his loins all the men who have appeared, or ever will appear, on the face of the earth. Every seed, and every animal, according to this doctrine, must have included in its own body an infinite posterity. If we yield to reasonings of this kind, we must lose sight of truth in the labyrinths of infinity; and, in place of solving, or of throwing light upon the question, we will involve it in tenfold obscurity. It is removing the object beyond the reach of our vision, and then complaining that it cannot be seen.

Let us investigate the nature of the ideas of

infinite progression and expansion. How do we acquire them? In what do they instruct us? We derive the idea of infinity from the idea of what is limited. It is in this manner we obtain the ideas of infinite succession, and geometrical infinity: every individual is a unit; several individuals make a limited number; and a whole species is to us an infinite multitude. From the same data, by which we have demonstrated the nonentity of geometrical infinity, we might prove that infinite succession, or propagation, rests on no firmer basis; that it is only an abstract idea, a mere deduction from the idea of finite objects, by lopping off the limits which necessarily terminate every magnitude*; and, of course, that every opinion which infallibly leads to the idea of actual existence, upon no better authority than what is derived from geometrical or numerical infinity, ought to be rejected.

The partizans of this opinion are now reduced to the necessity of acknowledging, that their infinity of succession and of multiplication is only an indeterminable or indefinite number. But, say they, the first seed, of an elm, for example, which weighs not a grain, actually contains all the organic particles requisite for the formation of this tree, and of all the individuals of the same species which shall ever appear. Is this a solution of the difficulty? Is it not cutting the knot, in place of untying it?

When in reply to the question, how beings

* See this fully demonstrated in my preface to the French translation of Newton's Fluxions, p. 7.

are multiplied? it is answered, that the multiplication was completed in the creation of the first individuals, is not this both an acknowledgment of ignorance, and a renouncing of all desire of farther improvement? We ask how one being produces its like? and we receive for answer, that the whole was created at once. A strange solution; for, whether one only or a thousand generations had passed, the same difficulty remains, and, instead of removing it, the supposition of an indefinite number of germs, all existing and contained in a single germ, increases and renders it altogether incomprehensible.

I allow, that it is much easier to find fault, than to investigate truth, and that the question concerning reproduction is perhaps of such a subtile nature, as not to admit of a full and satisfactory explication. But we ought at least to inquire whether it be altogether inscrutable; and, in the course of this inquiry, we will discover all that can be known, and the reason why we can know no more.

Questions or inquiries are of two kinds; the first regard primary causes, the other particular effects. If, for example, it be asked why matter is impenetrable? we must either return no answer, or reply by saying, that matter is impenetrable, because it is impenetrable. The same answer must be made, if we inquire into the cause of gravity, of extension, of the inertia of bodies, or of any general quality of matter. Such is the nature of all general and abstract qualities, that, having no mode of comparing them with other

objects in which they do not exist, we are totally incapable of reasoning concerning them; and therefore all inquiries of this kind, as they exceed the powers of human intellect, are perfectly useless.

But, on the other hand, if the reason of particular effects be demanded, we are always in a condition to give a distinct answer, whenever we can show that these effects are produced by one of the general causes; and the question is equally solved, whether the particular effect proceeds immediately from a general cause, or from a chain of successive effects, provided we have a clear conception of the dependence of these effects upon each other, and of their mutual relations.

But, when a particular effect appears not to have any dependence upon more general effects, or has no analogy to those already known, we are then totally unable to give any explication of such effect; because we have no similar object with which it can be compared. We cannot explain a general cause, because it equally exists in every object; and, on the contrary, we can give no account of a single or isolated effect; because the same quality exists not in any other subject. To explain a general cause, we must discover one still more general; but a single and detached effect may be illustrated by the discovery of an analogous effect, which experience or accident may exhibit.

There is still another kind of question, which may be called a question of fact. For example,

why do trees, dogs, &c., exist? All questions of this kind are perfectly insolvable; for those who solve them by final causes consider not that they mistake the effect for the cause: the relation of particular objects to ourselves has no connexion with their origin. Moral affinity or fitness can never become a physical reason.

Questions in which we employ the word *why*, ought to be carefully distinguished from those in which we employ *how*, and still more from those in which we ought to use the words *how much* or *how many*. *Why* always relates to the cause of the effect, or to the effect itself; *how* relates to the manner in which the effect happens; and *how much* relates to the measure or quantity of the effect.

These distinctions being established, let us now examine the question concerning the reproduction of beings. If it be demanded *why* animals and vegetables continue their species? we clearly perceive that this is a question of fact, and therefore it is useless and insolvable. But, if it be asked *how* animals and vegetables are reproduced? we are enabled to solve the question, by giving the history of the generation of every species of animal, and of the reproduction of every species of plant: after tracing, however, every possible method of propagation, and making the most exact observations, we have learned the facts only, but have not discovered the causes: and, as the means Nature employs in multiplying and containing the species, seem to have no relation to the effects produced; we

are still under the necessity of asking, by what secret cause she enables beings to propagate their kinds.

This question is very different from the first and second. It admits of nice scrutiny, and even allows us to employ the powers of imagination. It is, therefore, by no means insolvable; for it belongs not to a general cause. Neither is it solely a question of fact: and if we can conceive a method of reproduction, depending on primary causes, or which, at least, is not repugnant to them, we ought to be satisfied with it; and the more relation it has to the other effects of Nature, it will rest upon a firmer basis.

By the nature of the question, then, we are permitted to form hypotheses, and to choose that which appears to have the greatest analogy to the other phænomena of Nature. But we ought to reject every hypothesis which supposes the thing to be already accomplished; such, for example, as that which supposes the first germ to contain all the germs of the same species, or that every reproduction is a new creation, an immediate effect of the will of the Deity; for all hypotheses of this kind are mere matters of fact, concerning which it is impossible to reason. We must likewise reject every hypothesis which is founded on final causes, such as, that reproduction is ordained in order to replace the living for the dead; that the earth may always be covered with vegetables and peopled with animals; that men may be supplied with abundance of nourishment, &c.; for such hypotheses, in place

of explaining the effect by physical causes, stand on no other foundation than arbitrary relations and moral affinities. We ought, at the same time, to despise those general axioms and physical problems, so frequently and so injudiciously employed as principles by some philosophers, such as, "Nulla fœcundatio extra corpus;" every living creature proceeds from an egg; generation always supposes sexes, &c. These maxims must not be taken in an absolute sense; they signify no more than that the thing happens more commonly in this manner than in any other.

Let us then endeavour to find an hypothesis that will be liable to none of these defects or incumbrances; and, if we shall not succeed in explaining the mechanism employed by Nature for the reproduction of beings, we shall, at least, be able to approach nearer to the truth than we have hitherto reached.

In the same manner as we make moulds by which we can bestow on the external parts of bodies whatever figure we please, let us suppose, that Nature can form moulds by which she bestows on bodies both an external and internal figure; would not this be one method by which reproduction might be effected?

Let us first consider whether this supposition be well founded; let us examine whether it contains any thing that is absurd or contradictory; and then we shall discover what consequences may be drawn from it. Though our senses reach not beyond the external parts of

bodies, we have clear ideas of their different figures and external affections, and we can imitate Nature, by representing external figures in different ways, as by painting, by sculpture, and by moulds. But, though our senses be limited to external qualities, we know that bodies possess internal qualities, some of which are general, as gravity. This quality or power acts not in proportion to the surfaces, but to the masses, or the quantities of matter. Thus there are in Nature powers, and even of the most active kind, which penetrate the internal parts of matter. We are unable to form distinct ideas of such qualities; because, not being external, they fall not under the cognisance of our senses. But we can compare their effects, and may draw analogies from them, in order to account for the effects of similar qualities.

If our eyes, instead of representing to us the surfaces of bodies only, were so constructed as to perceive their internal parts alone, we should then have clear ideas of the latter, without knowing any thing of the former. Upon this supposition, moulds for the internal constitution, which I have supposed to be employed by Nature, would be equally obvious and easy to conceive as *moulds for the external figures of bodies*; and we should then be in a condition to imitate the internal parts of bodies, as we now imitate the external. These internal moulds, though beyond our reach, may be in the possession of Nature, as she endows bodies with gravity, which penetrates every particle of mat-

ter. The supposition of internal moulds being thus founded on analogy, let us next examine whether it involves any contradiction.

It may be alleged, that the expression *internal mould*, includes two opposite and contradictory ideas; for the idea of a *mould* relates only to the surface; but the idea of internal, as here employed, has a relation to the whole mass; and therefore we might, with equal propriety, talk of a massy surface as of an internal mould.

I allow, that, when ideas are attempted to be represented which have never been expressed, we are sometimes obliged to use terms that are apparently contradictory. To avoid this inconvenience, philosophers have been accustomed to employ unusual terms, instead of those which have a received signification. But this artifice is of no use, when we can show, that the seeming contradiction lies in the words, and not in the idea. A simple idea, however, cannot include a contradiction; *i. e.* whenever we can form an idea of a thing, if this idea be simple, it cannot be complex; it can include no other idea; and, of course, it can contain nothing that is opposite or contradictory.

Simple ideas are not only the first apprehensions received by the senses, but the first comparisons, which we form of these apprehensions: for the first apprehension is always the result of comparison. The idea of the largeness or distance of an object necessarily implies a comparison with bulk or distance in general. Thus, when an idea includes nothing more than comparison, it ought to be regarded as simple; and,

consequently, it can contain nothing contradictory. The idea of an internal mould is of this species. There is in nature a quality known by the name of gravity, which penetrates the internal parts of bodies. I understand the idea of an internal mould to be relative to gravity; and, therefore, as it includes only a comparison, it can imply no contradiction.

Let us now trace the consequences which may be drawn from this supposition; let us likewise investigate such facts as may correspond with it; and the more analogies we can collect, the supposition will be rendered the more probable. We shall begin with unfolding the idea of internal moulds; and then explain how it may lead us to conceive the mode of reproduction.

Nature, in general, appears to have a greater bias towards life than death: she seems anxious to organize bodies as much as possible. Of this the multiplication of germs, which may be infinitely increased, is a convincing proof; and it may be safely affirmed, that, if all matter is not organized, it is only because organized beings destroy one another; for we can increase at pleasure the number of animals and vegetables; but we cannot augment the quantity of stones or of dead matter; which seems to indicate, that the most ordinary and familiar operation of Nature is the production of organized bodies; and here her power knows no limitation.

To render this idea more plain, we shall calculate what may be produced by a single germ. The seed of an elm, which weighs not above the

hundredth part of an ounce, will, in 100 years, form a tree, of which the mass will amount to ten cubic fathoms. But, at the tenth year, this elm will have produced 1,000 seeds, each of which, in 100 years more; will consist of ten cubic fathoms. Thus, in the space of 110 years, more than 10,000 cubic fathoms of organized matter are produced. Ten years after, we shall have 10,000,000 of fathoms, without including the annual increase of 10,000, which would amount to 100,000 more; and, in ten years more, the number of cubic fathoms would be 10,000,000,000,000. Hence, in 130 years, a single germ would produce a mass of organized matter equal to 1,000 cubic leagues; for a cubic league contains only about 10,000,000,000 cubic fathoms. Ten years after, this mass would be increased to 1,000 times 1,000 leagues, or 1,000,000 of cubic leagues; and in ten more, it would amount to 1,000,000,000,000 cubic leagues; so that, in the space of 150 years, the whole globe might be converted into organized matter of a single species. Nature would know no bounds in the production of organized bodies, if her progress were not obstructed by matter which is not susceptible of organization; and this is a full demonstration that she has no tendency to increase brute matter; that her sole object is the multiplication of organized beings; and that, in this operation, she never stops but when irresistible obstacles occur. What we have remarked concerning the seed of an elm may be extended to any other germ; and it would be easy to show, that, by hatching all the eggs

which are produced by hens for a course of thirty years, the number of fowls would be so great as to cover the whole surface of the earth.

Calculations of this kind evince the tendency of Nature towards the production of organized bodies, and the facility with which she performs the operation. But I will not stop here. Instead of dividing matter into *organized* and *brute matter*, the general division ought to be into *living* and *dead matter*. That *brute matter* is nothing but matter produced by the *death* of animals and vegetables, might be proved from the enormous quantities of shells, and other relics of living bodies, which constitute the principal parts of stones, marbles, clays, marls, earths, turfs, and other substances that are commonly reckoned *brute matter*, but are, in reality, composed of decayed animals and vegetables. This doctrine will be farther illustrated by the subsequent remarks, which appear to be well founded.

The great facility and activity of Nature in the production of organized bodies, the existence of infinite numbers of organic particles which constitute life, have been already shown. We now proceed to inquire into the principal causes of death and destruction. In general, beings which have a power of converting matter into their own substances, or of assimilating the parts of other beings, are the greatest destroyers. Fire, for example, which converts almost every species of matter into its own substance, is the greatest source of destruction that we are acquainted with. Animals seem to partake of the nature of

flame; their internal heat is a species of fire approaching to flame. Accordingly, animals are the greatest destroyers; and they assimilate and convert into their own substance all bodies which can serve them for nourishment. But, though these two causes of destruction be considerable, and their effects tend perpetually to the destruction of organized bodies, the cause of reproduction is infinitely more active and powerful. It even seems to derive, from destruction itself, fresh powers of multiplying; for assimilation, which is one cause of death, is, at the same time, a necessary mean of producing life.

The destruction of organized bodies, as has been remarked, is only a separation of the organic particles of which they are composed. These particles continue separate till they be again united by some active power. But what is this power? It is the power, possessed by animals and vegetables, of assimilating the matter of their food; and is not this the same, or nearly connected with the same power which is the cause of reproduction?

CHAP. III.

Of Nutrition and Growth.

AN animal body is a kind of internal mould, in which the nutritive matter is so assimilated to the whole, that, without changing the order or proportion of the parts, each part receives an augmentation. This increase of bulk has, by some philosophers, been called an expansion or unfolding of the parts, because they fancied they had accounted for the phænomenon, by telling us, that the form of an animal in embryo was the same as at full maturity, and that, therefore, it was easy to conceive how its parts should be proportionally unfolded and augmented by the addition of accessory matter.

But how can we have a clear idea of this augmentation or expansion, if we consider not the bodies of animals, and each of their parts, as so many internal moulds which receive the accessory matter in the order that results from their position and structure? This expansion cannot be effected solely by an addition to the surfaces. but, on the contrary, by an intus-susception, or by penetrating the whole mass; for the size of the part is augmented proportionally, without

changing its form. Hence it is necessary, that the increasing matter must, in some manner or other, intimately penetrate the whole part in all its dimensions: it is equally necessary that this penetration should be effected in a fixed order and proportion, so that no internal point receive more matter than another; otherwise some parts would be more quickly unfolded than others, which would entirely change their figure. What can thus regulate the accessory matter, and force it to arrive equally and proportionally to every internal point of the body, if we have not recourse to an internal mould?

The bodies of animals and of vegetables, therefore, consist of internal moulds, which uniformly preserve the same figure. But their masses may receive a proportional increase, by the expansion of the moulds in all their dimensions, both internal and external; and this expansion is effected by an intus-susception of an accessory and foreign matter, which intimately penetrates the whole, and assumes the same form and identity of substance with the matter of the moulds themselves.

But what is the nature of that matter which an animal or a vegetable assimilates to its own substance? What bestows on it that force and activity which enables it to penetrate the internal mould? If such a power exists, must it not be similar to that by which the mould itself is capable of being reproduced?

These three questions include the whole subject, and appear to depend on one another; for

it is impossible to explain, in a satisfactory manner, the reproduction of animals or vegetables, if we have not a clear idea how the operation of nutrition is performed. Each question, therefore, demands a separate examination, that we may be enabled to compare their results.

The first, which regards the nature and qualities of the nutritive matter, is in part resolved by the preceding reasonings, and shall be clearly unfolded in the subsequent chapters. We shall show, that there are in Nature infinite numbers of living organic particles; that Nature produces them without any expense, because their existence is constant and invariable; that the causes of death disunite these particles only, but do not destroy them. Thus the matter assimilated by an animal or vegetable, is an organic matter of the same nature with that of the animal or vegetable, and, consequently, may augment the size without changing the figure or the qualities of the original moulds; because it has the same qualities and the same form with the matter of which the moulds themselves are composed. Of the quantity of aliment taken by an animal to support its life and to maintain the vigour of its organs, and of the juices absorbed by the roots and leaves of a plant, a great part is rejected by transpiration, by secretions, and by other excretories; and a small portion only is retained for the nourishment and expansion of the parts. It is extremely probable, that, in the bodies of animals and of vegetables, a separation is made between the *brute* particles of

the aliment and the organic; that the former are carried off by the methods just mentioned; that nothing but the organic particles remain; and that they are distributed, by means of some active power, to the different parts, in a proportion so exact, that neither more nor fewer are applied than answer the purposes of nutrition, and of an equal growth and expansion.

As to the second question, What is the nature of that active power, which enables the organic matter to penetrate and combine with the internal mould? It is apparent, from the preceding chapter, that powers exist in Nature, like that of gravity, which affect the most internal parts of matter, without having the smallest relation to its external qualities. These powers, as formerly observed, are beyond the reach of our senses; because their action is exerted upon the intimate structure of bodies. It is evident, therefore, that we can never obtain a clear idea of them, nor of their mode of acting. Their existence, however, is not less certain, than that, by means of them, most natural effects are produced, especially those of nutrition and expansion, which must be owing to a cause that penetrates the most intimate recesses of the original moulds; for, in the same manner as gravity pervades the whole parts of matter, the power which pushes forward or attracts the organic particles of food, penetrates the internal parts of organized bodies; and as these bodies have a certain form, which we have distinguished by the appellation of *internal moulds*, the organic particles, pushed

on by the action of this penetrating force, must enter in an order relative to this form, and consequently cannot alter its figure, but only augment its bulk, and give rise to the growth and expansion of organized bodies: and if, in the organized body, thus expanded, there be some particles similar to the whole, both internally and externally, these parts will become the source of reproduction.

Let us now examine the third question, namely, Is it not by a similar power that the internal mould itself is reproduced? This power appears to be not only similar, but the very same with that which is the cause of expansion and reproduction; for, in an organized and expanded body, nothing farther is necessary for the reproduction of a new body similar to itself, than that it should contain some particle every way similar to the whole. This particle, at its first separation, will not present to our eyes a sensible figure, by which we can compare it with the whole body. But, when separated from the body, and put in a situation to receive proper nourishment, this similar particle will begin to expand and to exhibit the form of an entire and independent being, of the same species with that from which it was detached. Thus, a willow or a polypus, as they contain a larger proportion of particles similar to the whole, than most other substances, when cut into any indefinite number of pieces, each segment becomes a new body similar to the parent from which it was separated.

Now, in a body of which all the particles are

similar to itself, the organization is the most simple, as has been remarked in the first chapter; for it is only a repetition of the same form, a congeries of figures similarly organized. It is for this reason that the most simple bodies, the most imperfect species, are most easily and most abundantly reproduced. But, if an organized body contain only few particles similar to itself, as these alone are capable of a second expansion, its power of reproducing will be both more difficult, and more circumscribed as to the number produced. The organization of bodies of this last kind is also more complex, because it possesses fewer parts which are similar to the whole; and, therefore, the more perfectly a body is organized, its power of reproduction will be proportionally diminished.

In this manner we discover nourishment, growth, and propagation, to be effects of the same cause. Organized bodies are nourished by the particles of aliment which are similar to them; they grow or are expanded by absorbing those organic particles which correspond to their own nature; and they propagate, because they contain some organic particles similar to themselves. It only remains to examine whether these similar organic particles are extracted from the food, or have a primary and independent existence in the bodies themselves. If we suppose the latter, we recur to the infinity of similar parts or germs contained within each other, an hypothesis which we have already shown to be replete with difficulties and absurdities. We must, therefore,

maintain, that the similar parts are extracted from the food; and, after what has been said on the subject, we hope to be able to explain the manner of their absorption, and how the more minute organic particles which compose them are united.

We formerly remarked, that the organic parts of food were separated from those which have no analogy to the animal or vegetable, by transpiration and other excretions. The first remain, and serve to expand and nourish the body: but these organic parts must be of very different species; and, as each part of the body receives only a proper number of those which correspond to it, the surplus, it is natural to imagine, will be returned from all parts of the body, and be collected in one or more reservoirs, where they will unite and form small organic bodies similar to the first, and which require nothing but proper circumstances for expanding and becoming new individuals of the same species; for, as all parts of the body send off organic particles similar to those of which themselves are composed, the result of their union must be the production of new organized bodies similar to the original. Hence we may conclude, that this is the reason why organized bodies, during the time of their growth and expansion, are seldom or never capable of reproducing; because the growing parts absorb the whole organic particles presented to them, and, no surplus being sent from the different parts of the body, propagation becomes, of course, impracticable.

This account of nutrition, and of reproduction, will not, perhaps, be received by those philosophers who admit only a certain number of mechanical principles, and reject every thing as false which depends not upon them; and, as the explication now given of nutrition and reproduction has no connexion with any of these principles, they will conclude that it deserves no credit. But I think very differently from these philosophers. In admitting only a few mechanical principles, they consider not how much they contract the bounds of philosophy, and how few phænomena can, by this narrow method of thinking, be fully explored.

The notion of explaining all the appearances in Nature upon the principles of mechanism, is, doubtless, a great exertion, and was first attempted by Des Cartes. But it is, at least, an untenable project; and, though it were otherwise, we are unable to put it in execution. These mechanical principles are, the extension of matter, its impenetrability, its motion, its external figure, its divisibility, the communication of motion by impulse, by the action of springs, &c. These ideas we have acquired by our senses, and we regard them as principles, because they are general and common to all matter. But are we certain that matter possesses no other qualities? Ought we not rather to believe that these qualities, which we assume for principles, are only modes of perception; and that, if the conformation of our senses were different, we would recognise qualities in matter very different from

those above enumerated? It is presumptuous to deny every quality to matter but those we are acquainted with. Many general qualities, perhaps, remain to be discovered; and many may exist which will for ever elude human discernment. The cause of impulsion, of cohesion, or of any other mechanical principle, will always continue to be equally inscrutable as that of attraction, or of any other general quality. Hence it may be concluded, that mechanical principles are nothing else than general effects which experience has enabled us to remark in matter; and that, whenever we shall discover, either by reflection, by analogy, or by experience, a new general effect, it will become a new mechanical principle, which may be employed with equal advantage and certainty as any of those that are already known.

The defect of Aristotle's philosophy was the employing particular effects as causes; and that of Des Cartes consists in the rejection of every cause, but a few general effects. To use nothing as causes but general effects, to endeavour to augment the number of these, and to attempt to generalize particular effects, would constitute the most perfect principles of genuine philosophy.

In my theory of expansion and reproduction, I first admit the mechanical principles, then the penetrating force of gravity, and, from analogy and experience, I have concluded the existence of other penetrating forces peculiar to organized bodies. I have proved, by facts, that matter has a strong tendency towards organization; and

that there are in Nature an infinite number of organic particles. I have, therefore, only generalized particular observations, without advancing any thing contrary to mechanical principles, when that term is used in its proper sense, as denoting the general effects of Nature.

CHAP. IV.

Of the Generation of Animals.

AS the organization of man, and of other animals, is the most perfect, and the most complex, the propagation of them is likewise most difficult, and the number of individuals is less abundant. I except here such animals as can be multiplied by a separation of their parts, or without the aid of generation, these having been sufficiently treated of in the preceding chapter*.

But how will the theory delivered in the former chapter apply to the generation of men, and other animals, who are distinguished by sexes? We understand, from what has been said, how every individual may reproduce; but we cannot conceive how two individuals, the one a male, and the other a female, should uniformly produce a third.

Before replying to this objection, I must observe, that the writers on this subject have confined their ideas solely to the generation of men

* Here the author gives an unnecessary recapitulation of chap. iii. to which the reader is referred.

and of animals, without attending to the nature of reproduction in general: and as the generation of animals is the most complicated species of reproduction, they have laboured under great disadvantages, not only by attacking the most difficult point, but by leaving themselves no subject of comparison to enable them to illustrate the question. To this circumstance I chiefly attribute the unsuccessfulness of their attempts. But, by the method I have observed, I am persuaded that I shall be able to give a satisfactory explanation of every species of reproduction.

Let the generation of man serve as an example. To begin with infancy.

The expansion and growth of the different parts of man's body being effected by the intimate penetration of organic particles, analogous to each of these parts, all the organic particles, in early life, are absorbed, and entirely employed in unfolding and augmenting his different members. He has, of course, little or no superfluous particles, till his growth be completed. It is for this reason that infants are incapable of propagating. But, when man's body has nearly attained its full size, he requires not the same quantity of organic particles; the surplus is, therefore, sent from all parts into reservoirs destined for their reception. These reservoirs are the testes and seminal vessels. At this very period, when the growth of the body is nearly finished, puberty commences, and every phænomenon attending it discovers a superabundance

of nourishment: the voice changes into a deeper tone; the beard begins to appear, and other parts of the body are covered with hair; the parts destined for generation are suddenly expanded; the seminal fluid fills the reservoirs prepared for its reception, and spontaneously escapes from the body during sleep. This superabundance is still more evident in the female: it discovers itself by a periodic evacuation, which begins and terminates with the faculty of propagating, by a quick increase of the breasts; and by a change in the sexual parts, which shall be afterwards explained*.

I conceive, then, that the organic particles sent from all parts of the body into the testicles and seminal vessels of the male, and into the ovarium of the female, compose the seminal fluid which, in either sex, as formerly observed, is a kind of extract from the several parts of the body. These organic particles, instead of uniting and forming an individual similar to that in whose body they are contained, as happens in vegetables, and some imperfect animals, cannot accomplish this end without a mixture of the fluids of both sexes. When this mixture is made, if the organic particles of the male exceed those of the female, the result is a male; and if those of the female abound most, a female is generated. I mean not that the organic particles of the male or of the female could singly produce

* See below the Nat. Hist. of Man, chap. iii.

individuals: a concurrence or union of both is requisite to accomplish this end. Those small moving bodies, called *spermatic animals*, which, by the assistance of the microscope, are seen in the seminal fluids of all male animals, are, perhaps, organized substances proceeding from the individual which contains them; but, of themselves, they are incapable of expansion, or of becoming animals similar to those in whom they exist. We shall afterwards demonstrate, that there are similar animalcules in the seminal fluids of females, and point out the place where this fluid is to be found.

It is probable, that these organic bodies are only the first rudiments of an animal, containing nothing but its essential parts. We shall not enter into a detail of proofs on this subject, but content ourselves with remarking, that the organization of these pretended spermatic animals may be very imperfect; or rather, that they are the living organic particles mentioned above, which are common both to vegetables and to animals; or, at most, that they are only the first junction of these particles.

But, to return to our subject. It may be asked, how is it possible that the superfluous organic particles should be detached from all parts of the body, and unite upon the mixture of the male and female fluids? Besides, are we certain that such a mixture takes place? Has it not been maintained, that the female furnishes no fluid of this kind? Is it an established fact, that the male fluid enters the uterus? &c.

To the first question I reply, that, if what I have said concerning the penetration of the internal mould by the organic particles, in growth and nutrition, had been properly understood, it would be easy to conceive, that, when these particles are unable to penetrate the parts into which they formerly entered, they must take another route, and, of course, arrive at some other part, as the testicles and seminal vessels. Every attempt to explain the animal economy, and the various motions of the human body, by mechanical principles alone, must be vain and ineffectual: for it is evident, that the circulation of the blood, muscular motion, and other functions of an animated body, cannot be accounted for by impulsion, or by any of the common laws of mechanism. It is equally evident, that growth and reproduction are effects of laws of a different nature. Why, then, do we refuse the existence of penetrating forces which act upon the whole substances of bodies, when we have examples of such powers in gravity, in magnetic attraction, in chemical affinities? Since, therefore, we are assured by facts, and by a number of constant and uniform observations, that there are powers in nature which act not by impulsion, why are not these powers ranked among mechanical principles? Why do we reject them in the explanation of effects which they are known to produce? Why are we desirous of employing the power of compulsion only? Is not this equally absurd as to judge of painting by the touch; to explain the phænomena which belong to the mass by those

that relate only to the surface; or to use one sense in place of another? It is limiting the reasoning faculty to a small number of mechanical principles, which are by no means sufficient to explain the various effects of Nature.

But, if these penetrating forces be admitted, is it not natural to imagine, that those particles which are most analogous to one another will unite in the most intimate manner; that each part of the body will appropriate those which are most agreeable to its nature; and that the whole superfluous particles will form a seminal fluid, which shall contain all the organic particles necessary for forming a small organized body, similar in every respect to that from which the fluid is extracted? May not a force similar to that which is the cause of growth, be sufficient to collect the superfluous organic particles, and bestow on them the figure of the body from which they proceed?

That our food contains an immense number of organic particles, requires no formal proof; since we are solely nourished by animals and vegetables, which are organized substances. In the stomach and intestines, the gross parts of the aliment are separated and rejected by the excretories. The chyle, which is a purer part of the aliment, is absorbed by the lacteal vessels; from thence it is carried into the mass of blood, and, in the course of circulation, it is more and more refined, the unorganic and useless particles being thrown out by transpiration and other secretions; but the organic particles are retained, because

they are analogous to the blood, and are attracted by it. Hence, as the whole mass of blood passes several times through the body, during the course of this perpetual circulation, I suppose, that each particular part attracts those particles which are most analogous to it, and allows the rest to move on. In this manner all the parts are nourished and unfolded, not, as is commonly imagined, by a simple addition of matter to their surfaces, but by an intimate penetration of substance, effected by a force which acts equally upon every point of the whole mass: and, after the different parts have acquired their utmost growth, and are fully impregnated with similar organic particles, as their substance becomes then more dense and solid, I imagine that they lose their faculty of attracting and receiving the particles presented to them. But, as the particles continue to be carried round in the course of the circulation, and are no longer absorbed in such quantities as formerly, they must, of necessity, be deposited in some particular reservoir, such as the testicles and seminal vessels. When this fluid extract of the male is mixed with that of the female, the particles which are most analogous to each other, being actuated by a penetrating force, unite and form a small organized body, similar to the one or the other sex; and this body, when once formed, requires only an expansion of its parts, an operation which is performed in the womb of the mother.

We shall now consider the second question, namely, Whether the female has a seminal fluid

similar to that of the male? In the *first* place, though such a fluid exists in females, the mode of emission is very different from that of the male, being generally confined within the body*. The ancients were so confident of the existence of a female fluid, that they distinguished the two sexes by their different modes of emission. But those physicians who attempt to explain generation by eggs, or by spermatic animalcules, insist, that females have no peculiar fluid; that the mucus issuing from the parts has been mistaken for a seminal fluid; and that the opinion of the ancients on this subject is destitute of foundation. This fluid, however, does exist; and the doubts concerning it have arisen solely from attachment to systems, and from the difficulty of discovering its reservoir. The fluid which is separated from the glands about the neck and orifice of the uterus, has no visible reservoir; and, as it flows out of the body, it is natural to think that it is not the prolific fluid, because it cannot cooperate in the formation of the fœtus, which is performed within the uterus. The reservoir for the prolific fluid of the female, therefore, must be situated in a different part: it even flows abundantly; though, like that of the male, a small quantity is sufficient to produce a fœtus. If a little of the male fluid enters the uterus, either by its orifice or by absorption, and meets with the smallest drop of the female fluid,

* Quod intra se semen jacit, fœmina vocatur; quod in hac jacit, mas. Aristot. de Animalibus, art. 18.

it is sufficient for the purpose of propagation. Thus, neither the observations of some anatomists, who maintain that the seminal fluid of the male can have no admission into the uterus, nor the opposite opinion maintained by their antagonists, have any influence upon the theory we are endeavouring to establish. But the discussion of these points we leave to a future opportunity.

Having obviated such objections as might be made, let us attend to the evidences which concur in supporting our hypothesis. The first arises from the analogy between growth and reproduction. It is impossible to give a satisfactory account of growth or expansion, without having recourse to those penetrating forces, those affinities or attractions, which we employed in explaining the formation of the small organic bodies, that are similar to the large bodies which contain them. A second analogy is derived from this circumstance, that both nutrition and reproduction proceed, not only from the same efficient, but from the same material cause, namely, the organic particles of food; and what proves the surplus of the nutritive particles to be the cause of reproduction is, that the body is not in a condition to propagate till its growth be finished: of this we have daily examples, in dogs and other animals, who follow, more closely than we do, the laws of Nature: they have no inclination to propagate till they have nearly attained their full growth; and by this we know whether the growth of a dog be finished; for

he seldom grows after being in a condition to generate.

Another proof that the seminal fluid is formed of the surplus of the nutritive particles, arises from the condition of eunuchs and other mutilated animals: in this unnatural state, animals grow fatter than those who retain all their parts. The superabundance of nutriment, having no organs for its evacuation, changes the whole habit of their bodies. The knees and haunches of eunuchs grow uncommonly large. The reason is evident. After their bodies have acquired the common size, if the superfluous organic particles found an issue, as in other men, the growth would proceed no farther. But, as they want organs for emitting the seminal fluid, which is nothing but the superfluous nutritive particles, it remains in the body, and has a constant tendency to expand the parts beyond their natural size. Now, bones, it is well known, grow or extend by their extremities, which are soft and spongy, and when they have once acquired solidity, they are incapable of farther extension: hence the superfluous organic particles can only enlarge the spongy extremities of bones; and this is the reason why the haunches, knees, &c., of eunuchs augment to a disproportioned bulk.

But the strongest proof of the truth of our present doctrine arises from the resemblance of children to their parents. Sons, in general, resemble their fathers more than their mothers, and daughters have a greater resemblance to their mothers than their fathers; because, with regard

to the general habit of body, a man resembles a man more than a woman, and a woman resembles a woman more than a man. But, as to particular features or habits, children sometimes resemble the father, sometimes the mother, and sometimes both. A child, for example, will have the eyes of the father, and the mouth of the mother, or the colour of the mother, and the stature of the father. Of such phænomena it is impossible to give any explication, unless we admit that both parents have contributed to the formation of the child, and, consequently, that there has been a mixture of two seminal fluids.

These resemblances long embarrassed me, and, till I had maturely considered the subject of generation, led me into many errors and prejudices: and it was not without much thought, a minute examination of a great number of families, and a multiplicity of evidence, that I could prevail on myself to alter my former opinion, and to embrace what I now believe to be truth. But the objections which might occur concerning mulattoes, mongrels, mules, and particular parental resemblances, instead of opposing my theory, I despair not of being able to show that they bestow on it an additional strength.

In youth, the seminal fluid is less copious, but more stimulating. Its quantity continues to augment till a certain age; because, in proportion as we approach that age, the parts of the body become more solid, admit fewer nutritive particles, send back more of them to the common reservoirs, and, of course, augment the quantity

of the seminal fluid. Thus, if the external organs have not been used, middle-aged men, or even old men, procreate with more ease than young men. This is evidently the case with the vegetable tribes: a tree, the older it is, produces the greater quantity of fruit.

Young people, who, by forced irritations, determine an unnatural quantity of this fluid into the reservoirs prepared for its reception, immediately cease to grow, lose their flesh, and at last fall into consumptions. The reason is apparent: they lose, by premature and too frequent evacuations, the very substance which Nature intended for the nourishment and growth of their bodies.

Men who are thin, but not emaciated, and those who are plump, but not fat, are the most vigorous. Whenever the superabundant nutritive particles begin to form fat, it is always at the expense of the seminal fluid and other generative powers. When the growth of the different parts of the body is complete, when the bones have acquired full solidity, when the cartilages begin to ossify, and, lastly, when the parts almost refuse the admission of nutritive particles, then the fat augments considerably, and the quantity of seminal fluid diminishes; because the nutritive particles, instead of being sent back to the reservoirs, are arrested in every part of the body.

The quantity of seminal fluid not only increases till we arrive at a certain age, but it becomes more thick. It contains, in the same

bounds, a greater quantity of matter. Its specific gravity is nearly double that of the blood; and, of course, it is heavier than any other animal fluid.

To a man in health, an evacuation of this fluid whets the appetite: he soon finds the necessity of repairing the loss by fresh nourishment. Hence we may conclude, that abstinence and hunger are the most effectual checks to luxury of every kind.

Many other remarks might be made on this subject, which must be deferred till we come to treat of the history of man: we shall, therefore, conclude with a few observations. Most animals discover no inclination for the sexes till their growth be nearly finished; those which have but one season in the year, have no seminal fluid, except at that time. Mr. Needham * not only saw this liquor forming in the milt of the *Calmar*, but likewise the spermatic animals, and the milt itself, which have no existence till the month of October, when this fish spawns on the coasts of Portugal, where Needham made the observation. After the spawning time is over, the seminal liquor, the spermatic animals, and the milt, dry up, and totally disappear, till the same season returns next year, when the superfluous nutritive particles renew the milt as formerly. The history of the deer will furnish us with an opportunity of remarking the various

* See Needham's New Microscopical Discoveries. London, 1745.

effects of rutting, the most conspicuous of which is the extenuation of the animal; and, in those species of animals whose rutting and spawning happens but once in a year, the extenuation of their bodies is proportionally great.

As women are smaller and weaker than men, as their constitutions are more delicate, and, as they take less food, it is natural to think that their superfluous organic particles should also be less abundant: of course, their seminal fluid will be weaker and smaller in quantity than that of men; and, since the fluid of females contains fewer organic particles, must not a greater number of males than of females result from a mixture of these two fluids? This is really the case; and to account for it has hitherto been deemed impossible. The number of males born exceeds that of females about a sixteenth part; and we shall afterwards see that the same effect is produced by the same cause in all the different species of animals.

CHAP. V.

Examination of the different Systems of Generation.

PLATO, in the Timæus, accounts not only for the generation of men, of animals, of plants, and of the elements, but even of the heavens and of the gods themselves, by images reflected or extracted from the divine Creator; which images, by an harmonic movement, are arranged in the most perfect order, according to the properties of number. The universe, he says, is a copy of the Deity; time, space, motion, and matter, are the images or representations of his attributes; and secondary and particular causes are results of the numeric and harmonic qualities of these images: the world, from its excellency, is the most perfect animated being. To give the world complete perfection, it was necessary that it should contain all the other animals, or all the possible forms and representations of the creative power. Man is one of these forms. The essence of all generation consists in the unity and harmony of the number Three, or of the Triangle, namely, that which generates, that in which generation is performed, and the result, or that which is generated. The succession of individuals in the

species is only a fugitive image of the immutable eternity of this harmonic triangle, a universal prototype of all existences, and of all generations.

This philosopher paints only ideas. Disengaged from matter, he flies into the regions of abstraction; and, losing sight of sensible objects, he contemplates those of intellect alone. One cause, one end, one mean, compose the whole of his perceptions: God is the cause, perfection the end, and harmonic representations the means. This idea is sublime; the mode of philosophizing is noble and full of simplicity; but it is perfectly vacant, and affords no objects for speculation. We are not pure intelligences. We are unable to give real existence to our ideas. Chained to matter, or rather depending on the causes of our sensations, it is impossible that we should realize abstractions. To Plato I might reply in his own manner, "The Creator realizes every thing he conceives; his perceptions beget existence: the created being, on the contrary, conceives nothing but by retrenching from reality; and annihilation is necessary to bring forth his ideas."

Let us, without regret, therefore, confine ourselves to a philosophy more humble and more material; and, keeping within the sphere which Nature has allotted us, let us examine those rapid and daring spirits, who attempt, though in vain, to fly beyond the limits of humanity. The whole of this Pythagorean philosophy, which is purely intellectual, depends upon two principles, the

one false, and the other uncertain; namely, the real power of abstraction, and the natural existence of final causes. To apprehend numbers to be real beings; to say that unity is a general individual, which not only represents all individuals, but even communicates existence to them; to pretend that unity exercises the actual power of engendering another unity nearly resembling itself, and of creating two individuals, two sides of a triangle, that can have no connexion or perfection without a third side, which is necessarily produced by the other two; in fine, to regard numbers, geometrical lines, and metaphysical abstractions, as real and efficient physical causes, by which the elements are formed, plants and animals regenerated, and all the phænomena of Nature produced, appears to be a most absurd abuse of human reason, and an invincible obstacle to the advancement of knowledge. Besides, nothing can be more fallacious than such chimeras. Supposing we should agree with Plato and Malbranche, that matter has no existence, that external objects are only ideal images of the creative power, and that we see every thing in the Deity himself; does it follow, that our ideas are of the same order with those of the Creator, and that they can produce real existences? Are we not dependent on our sensations? Whether the objects which excite sensations be real or imaginary, whether they exist without or within, whether it be God or matter that we every where behold, is to us of little importance: we are not less certain of

being uniformly affected in the same manner by the same causes. The relations between our senses and the objects which affect them are necessary and invariable. It is upon this basis alone that the principles of philosophy ought to be founded, otherwise our knowledge must be useless and fallacious. Can an harmonic triangle create the substance of the elements? Is fire, as Plato affirms, an acute triangle, and light and heat two properties of this triangle? Are water and air rectangular and equilateral triangles? Is the form of the element of earth a square, because, being the least perfect of the four elements, it recedes as far as possible from a triangle, without departing altogether from its essence? Do males and females embrace each other for no other purpose but to complete the triangle of generation? These Platonic ideas have two different aspects: in speculation, they seem to proceed from sublime principles; but the application of them in practice leads to nothing but false and childish conclusions.

Is it difficult to perceive that our ideas originate from our senses alone; that the objects we regard as real existences are those concerning which the senses uniformly give the same testimony; that the objects we apprehend as having a real existence, are those which are invariably presented to us in the same manner; that the mode in which they present themselves has no dependence upon our will or inclination; that, of course, our ideas, instead of being the causes

of things, are only particular effects, which become less similar to the objects themselves, in proportion as they are rendered more general; and, lastly, that mental abstractions are only negative beings, which derive their intellectual existence from the faculty we possess of considering objects without regarding their sensible qualities?

Is it not, therefore, apparent, that abstract ideas can never be the principles of existence, or of real knowledge? On the contrary, all our knowledge is derived from comparing and arranging the results of our sensations. These results are known by the appellation of *experience*, the only source of genuine science. The employment of any other principle is an abuse; and every edifice founded upon abstract ideas, is a temple erected to Error.

In philosophy, error has a more extensive influence than in morals. A thing may be false in morals solely because it is misrepresented. But falsehood in metaphysics consists not in misrepresentation alone, but in taking for granted what has no existence at all. It is into this most pernicious species of error that the Platonists and the Sceptics have fallen. Their false suppositions have obscured the natural light of truth, bewildered the reasoning faculties of men, and retarded the progress of philosophy.

Final causes are employed as a second principle by Plato and other theorists. This principle has even been adopted by the vulgar, and by some modern philosophers. A moment's re-

flection, however, will be sufficient to reduce this principle to its proper value. To say that light exists because we have eyes, and that sounds exist because we have ears; or to say that we have eyes and ears, because light and sounds exist; is not this precisely the same thing? or, rather, are we any wiser by this kind of reasoning? Will we ever make any discoveries by such a mode of explication? Is it not apparent, that final causes are only arbitrary relations and moral abstractions, which ought to have less influence than abstractions in metaphysics, because the origin of the former is less noble and worse imagined? And, though Leibnitz has endeavoured to give an elevation to final causes, under the appellation of the reasonableness and eternal fitness of things [*raison suffisante*], and Plato has represented them under the flattering picture of absolute perfection; all these efforts are insufficient to cover their native insignificance and precariousness. Are we better instructed in the operations of Nature, because we are told that nothing exists without a reason, or that every thing is created with a view to the perfection of the whole? What is reasonableness or fitness? What is perfection? Are they not moral beings, created solely by the human intellect? Are they not arbitrary relations which we have contrived to generalize? They have no foundation but in moral affinities, which, so far from producing any physical or real existence, change the nature of truth, and confound the objects of our

sensations, of our perceptions, and of our understandings, with those of our sentiments, of our passions, and of our wills *.

Much more might be said upon this subject.

* The translator thinks it his duty to apprise the reader, that here, as well as in several other parts of this work, the author makes an ingenious attack against the existence and utility of final causes. Every philosopher will admit the absurdity of employing a final cause as a physical principle. M. de Buffon, if he meant only to expose the misapplication of final causes, had no occasion to betray so much warmth and anxiety about an object so apparent. But, like too many of our modern French writers, he seems to neglect the distinction between final and physical causes. Final causes regard the design or the utility of particular objects, whether that utility relates to man, to the objects themselves, or to the general structure of the universe. But physical causes are limited to the explanation of particular effects, or modes of existence. *Why* were mountains, seas, or insects created? *What* useful purposes do they serve? For the solution of these, and similar questions, final causes can alone be employed. But if it be asked, *How* were mountains and seas formed? *How* were insects originally produced; and *how* are their different species propagated? These are questions purely physical.

It may be farther remarked, that final causes are the greatest stumbling blocks which lie in the way of atheists and materialists. They, accordingly, strain every nerve to remove them. But their force is so irresistible; their numbers are so immense; their beauties are so striking, and correspond so intimately with the warm and benevolent feelings of the heart; the concatenation and mutual dependence of all created beings recognisable by our senses are so apparent, and so illustrious, that no powers of sophistry, no artful misrepresentations, no strokes of ridicule, will ever be able to diminish their influence, or weaken the force of those sentiments which the Supreme Being intended they should excite in the breasts of his intelligent creatures. Final causes not-

But I pretend not to write a treatise on philosophy; and shall therefore return to physics, from which the ideas of Plato, concerning universal generation, have diverted my attention. Aristotle, who was as great a philosopher as Plato, and a better physician, instead of wandering in the regions of theory, collects facts, and speaks in a language more intelligible.

Matter, he remarks, which is only a capacity of receiving forms, assumes, in generation, a figure similar to the individual which furnishes it: and, with regard to animals which generate by the intervention of sexes, he imagines, that the prolific principle proceeds solely from the male*: for, though, in another place, when speaking of animals in general, he says, that the female sheds a seminal fluid within the body, it appears, that he regards not this fluid as a prolific principle; and yet he tells us, that the menstrual blood serves for the formation, nourishment, and growth of the fœtus; but that the efficient principle exists alone in the seminal fluid of the male, which acts not as matter but as a cause. Averrhoes, Avicenna, and other philosophers who embraced this opinion of Aristotle, have endeavoured to prove that females have no prolific fluid. They allege, that, as females are furnished with a menstrual fluid,

only demonstrate the existence of a Supreme Intelligent Power, but the infinite beneficence and minute attention of that Power to the happiness of those beings upon whom He has thought proper to confer existence.

* See Aristot. de Gen. lib. i. cap. 20, and lib. ii. cap. 4.

which is both necessary and sufficient for the purposes of generation, it is unnatural to suppose them possessed of any other, especially since it begins to appear, like that of the male, at the age of puberty. Besides, they continue, if females really have a prolific seminal fluid, why do they not produce without the intercourse of the male, since they contain the prolific principle, as well as the matter necessary for the growth and expansion of the embryo? This last reason is the only one which merits attention. The menstrual blood appears to be necessary for the growth and nourishment of the fœtus; but still it may contribute nothing to its first formation, which requires the mixture of both prolific fluids. Females, therefore, like males, may have a prolific fluid for the formation of the embryo, as well as menstrual blood for its growth and nourishment. The imagination is not unnatural, that, as the female possesses both a prolific fluid extracted from all parts of her body, and likewise the means of expanding and nourishing, she should produce females without any communication with the male. It must be allowed, that this metaphysical argument, used by the Aristotelians for proving that females are destitute of a prolific fluid, may be urged as the strongest argument against every system of generation, and, in particular, against that which I am endeavouring to establish.

Let us suppose, it may be said, that the superfluous organic particles are sent from every part of the body into the testicles and seminal vessels

of the male, why do they not, by means of your imaginary attracting forces, form small organized bodies similar to the whole? Why are not similar bodies generated in the female, without any intercourse with the male? If you answer, that the male fluid contains only males, that the female fluid contains only females, that both perish for want of the circumstances necessary for expansion, and that, for the procreation of an animal, a mixture of both is requisite; may it not be demanded, why this most complicated, difficult, and less fertile mode of generation, is so invariably preferred by Nature, that all animals, with a few trifling exceptions, generate by the mutual commerce of sexes?

I shall content myself, at present, with replying, that this is the mode actually employed by Nature; and, therefore, however complicated it may appear, it is, in fact, the most simple; because, as I formerly remarked, whatever most frequently happens is, in itself, however it may seem to us, the most simple.

Besides, the notion of the Aristotelians, that females have no seminal fluid, cannot receive our assent, if we consider the strong resemblance of children to their mothers, and that mules, mulattoes, and mongrels of every kind, uniformly resemble the mother more than the father; and, if it be farther considered, that the generating organs of the female, like those of the male, are properly formed for preparing and receiving a seminal fluid, we shall be easily induced to believe the existence of such a fluid, whether it re-

sides in the spermatic vessels, the testicles, or the ovaria, or proceeds, by irritation, from the lacunæ of De Graaf, which are situated at the neck and near the orifice of the uterus.

But we must examine Aristotle's ideas more fully, as, of all the ancients, this great philosopher has treated the subject of generation in the most extensive manner. He distinguishes animals into three classes: 1. Those that have blood, and, with few exceptions, propagate by copulation; 2. Those that have no blood, and, being hermaphrodites, produce of themselves without copulation; and, 3. Those that proceed from putrefaction, and have no parents of any kind. I shall first remark, that this division is exceedingly improper: though it be true, that animals having blood are distinguished into male and female, it is by no means equally true, that bloodless animals are, for the most part, hermaphrodites: for the only hermaphrodites we know, are land snails and worms; but we are uncertain whether all shell animals, and all those which have no blood, be also hermaphrodites. This must be learned from the particular histories of these animals. And, with regard to those which are alleged to proceed from putrefaction, as Aristotle gives no enumeration of them, many objections occur; for most species which the ancients believed to proceed from putrefaction, have, by the moderns, been discovered to proceed from eggs.

Aristotle makes a second division of animals, namely, into those which have the faculty of progressive motion, and those which have no such

faculty. All animals who move, and have blood, are distinguished by sexes: but those which, like oysters, adhere to one place, or hardly move at all, have no sexes, and, in this respect, resemble plants; and it is only, he observes, from difference in bulk that they have been distinguished into male and female. It must be acknowledged, that we are still uncertain whether shell animals have sexes: among oysters, some individuals are fertile, and others not. The fertile individuals are distinguished by a delicate edging or border which surrounds their bodies, and they are called males *. Our observations on this subject are extremely limited.

But to proceed. The male, according to Aristotle, contains the principle of motion, and the female the material part of generation. The organs destined for this purpose are different in different animals. Of these the testicles are the chief in males, and the uterus in females. Quadrupeds, birds, and cetaceous animals, have testicles; fishes and serpents are deprived of them; but they have two canals for the reception and maturation of the semen: these parts, so essential to generation, are always double both in males and females; and, in the male, they retard the motion of that part of the blood which goes to the formation of semen. This he proves from the example of birds, whose testicles swell considerably during the season of their amours, but afterwards

* See Deslandes dans son Traité de la Marine. Paris, 1747.

diminish so much, that they can hardly be discovered.

All quadrupeds covered with hair, and the cetaceous fishes, as whales and dolphins, are viviparous: but vipers and cartilaginous animals are not properly viviparous; because they produce an egg within their own bodies, previous to the exclusion of the live animal, Oviparous animals are of two kinds; those which produce perfect eggs, as birds, lizards, turtles, &c., and those which produce imperfect eggs, as fishes, whose eggs augment and come to perfection after they have been deposited in the water by the female: and, in every species of oviparous animals, except birds, the females are larger than the males, as in fishes, lizards, &c.

After remarking these general varieties in the animal kingdom, Aristotle begins with examining the opinion of the ancient philosophers, that the semen, both of the male and female, was extracted from all parts of the body; and he dissents from this opinion; because, says he, though children often resemble both father and mother, they sometimes also resemble their grandfathers. Besides, they resemble their fathers and mothers in the voice, in the hair, in the nails, and in the gait and manner of walking. Now, he proceeds, it is impossible for the semen to come from the hair, from the voice, from the nails, or from any external quality, as that of the mode of walking. Infants, therefore, do not resemble their parents because the semen

proceeds from all parts of the body, but for other reasons. I will not expose the weakness of these arguments; but shall only remark that this great man appears to have been anxious to differ from the sentiments of former philosophers: and I am persuaded, that, whoever peruses his treatise on generation, will discover that a strong passion for establishing a system different from that of the ancients, obliges him uniformly to prefer arguments of little probability to the force of proofs, when they stand in opposition to the general principles of his philosophy.

The seminal liquor of the male, according to Aristotle, is secreted from the blood; and the menstrual fluid of the female is likewise a secretion from the blood, and the only matter which contributes to generation. Females, he continues, have no other prolific fluid; no mixture, therefore, of male and female fluid takes place: this notion he attempts to prove by observing, that some women conceive without pleasure; that few emit any fluid during the time of copulation; that, in general, those who are brown, and have a masculine air, have no emission; and yet their powers of procreation are not less than those of a fairer complexion and more delicate appearance, who emit copiously. Thus, he concludes, women furnish nothing for the purposes of generation, but the menstrual blood. This blood is the matter of generation, and the male fluid contributes nothing but the form: the male fluid is the efficient cause, and the principle of motion; it is to generation what the sculptor is to a block

of marble: the seminal fluid is the sculptor, the menstrual blood the marble, and the fœtus the figure. The menstrual blood receives from the male semen a kind of soul, which gives it life and motion. This soul is neither material nor immaterial, because it can neither act upon matter, nor augment the menstrual blood, which is the only matter necessary to generation. It is a spirit, says our philosopher, similar to that of the element of the stars. The heart is the first production of this soul, which is the cause of its own growth, and of the growth and disposition of all the other members. The menstrual blood contains the *capacities* of all the parts of the fœtus; the soul or spirit of the male semen makes the heart begin to *act*, and communicates to it the powers of bestowing *action* on the other viscera; and in this manner the different parts of the animal are successively unfolded. All this appears clear and luminous to our philosopher. He has only one doubt, namely, whether the blood or the heart is first realized. And of this he doubted not without reason; for, though he adopted the opinion that the heart received its existence first, Harvey has since alleged, from arguments similar to those of Aristotle, that the blood, and not the heart, is first realized.

Thus have I given a short view of what Aristotle has delivered on the subject of generation, and shall leave the reader to consider whether any system of the ancients be more obscure, or more absurd, than that which he has endeavoured to establish. His system, however, has been

adopted by most men of learning. Harvey has borrowed many of Aristotle's notions; but he has also adopted some of his own, which are by no means better founded. It is not surprising that Aristotle's theory of generation, which was a result of his system of philosophy, where form and matter are the great principles, where vegetable and sensitive souls are the agents of Nature, and where final causes are real objects, should have been received in the schools: but it is not a little astonishing to see a physician and an acute observer, like Harvey, carried down the stream, while, at the same time, most philosophers followed the sentiments of Hippocrates and Galen, of which we shall afterwards take notice.

We mean not to convey a disadvantageous idea of Aristotle by the account we have given of his theory of generation. We might with equal propriety judge of Descartes by his treatise on man. What these two philosophers have remarked concerning the formation of the fœtus should rather be considered in the light of detached observations, or as consequences which each of them drew from their principles of philosophy, than as complete systems. Aristotle admits, with Plato, final and efficient causes: the latter are the sensitive and vegetable souls, that give form to matter, which, in itself, is only a *capacity* of receiving forms: and as, in generation, the female furnishes the greatest quantity of matter, and as it was repugnant to his system of final causes, that any effect should be

produced by two causes, when one was sufficient for the purpose, he concludes, that the woman alone contains the matter necessary for procreation: again, another of his principles is, that matter, in itself, has no form, and that *form* is a being distinct from matter; he therefore maintains, that the male furnishes the form, and, of course, that he contributes nothing *material.*

Descartes, on the contrary, admitted into his philosophy a few mechanical principles only. By these he attempted to explain the formation of the fœtus; and he imagined that he understood, and was able to communicate to others, the manner in which a living organized body could be formed by the laws of motion alone. The principles he employed were different from those of Aristotle. But both of them, instead of directing their inquiries to the subject itself, in place of examining it with impartiality, considered it only in relation to their philosophic principles, which could never be applied with success to the nature of generation, because it depends, as has been already shown, upon very different principles. Descartes, however, admits the existence and necessary concurrence of the seminal fluids of both sexes. He allows that both furnish something material for the purposes of generation; and that the fermentation occasioned by a mixture of the two fluids, is the cause of the formation of the fœtus.

Hippocrates, who lived about five or six hundred years before Aristotle, taught an opinion, which was adopted by Galen, and by most phy-

sicians, for many ages. He maintained the existence of a female fluid; and even that both male and female had two fluids, the one strong and active, the other weaker and more sluggish *. A concurrence of the two stronger fluids produced a male child, and of the two weaker a female. Thus, according to Hippocrates, there exist two kinds of seminal fluids both in the male and in the female. This notion he supports in the following manner: several women who produced girls only by their first husband, have had boys by their second; and the same thing has often happened to men who have had two wives. Supposing this to be fact, it admits of an easy explanation, without having recourse to two different fluids peculiar to each sex; for the women who had girls only by the first husband, and boys by the second, furnished a greater quantity of particles proper for generation during the first, than the second marriage; or the second husband furnished a greater quantity of *generating particles during the time of the second marriage*, than the first. If, at the moment of conception, the organic particles of the male are more abundant than those of the female, a male child is the result; and, when the organic particles of the female most abound, a female child is the consequence: it is not, therefore, surprising, that the husband should be foiled

* See Hippocrat. lib. de Genitura, p. 129, et lib. de Diæta, p. 198. Ludg. Bat. tom. i. 1665.

with some women, and have the superiority over others.

It is farther alleged by Hippocrates, that the male semen is secreted from the strongest and most essential fluids of the body; and he thus explains the manner in which the secretion is performed: "Venæ et nervi," says he, "ab omni corpore in pudendum vergunt, quibus dum aliquantulum teruntur, et calescunt ac implentur, velut pruritus incidit, ex hoc toti corpori voluptas ac caliditas accidit; quum vero pudendum teritur et homo movetur, humidum in corpore calescit ac diffunditur, et a motu conquassatur ac spumescit, quemadmodum alii humores omnes conquassati spumescunt.

"Sic autem in homine ab humido spumescente id quod robustissimum est ac pinguissimum secernitur, et ad medullam spinalem venit; tendunt enim in hanc ex omni corpore viæ, et diffundunt ex cerebro in lumbos ac in totum corpus et in medullam: et ex ipsa medulla procedunt viæ, ut et ad ipsam humidum perferatur et ex ipsa secedat; postquam autem ad hanc medullam genitura pervenerit, procedit ad renes, ac enim via tendit per venas; et si renes fuerint exulcerati, aliquando etiam sanguis defertur: a renibus autem transit per medios testes in pudendum, procedit autem non qua urina, verum alia ipsi via est illi contigua *," &c.

It will, doubtless, be perceived by anatomists,

* See Fesius's Translations, tom. i. p. 129.

that Hippocrates errs in tracing the route of the seminal fluid. But this error affects not his hypothesis, that the semen proceeds from every part of the body, and particularly from the head; because, he remarks, those who have had the veins behind their ears cut, secrete only a weak, and often unfertile semen. The female likewise sheds a seminal fluid sometimes within the uterus, and sometimes without it, when the orifice is too open. The male semen enters the uterus and mixes with that of the female; and as each has two species of fluid, the one strong and the other weak, if both of them furnish the strong kind, a male fœtus is the consequence; and, if both furnish the weak kind only, the result is a female: besides, if in the mixture there are more particles of the male than of the female fluid, the child will resemble the father more than the mother; *et e contra*. Here we might ask him what would happen, when the fluid of the one was strong and that of the other weak? I cannot conceive what reply could be made to this question: and, therefore, we are warranted to reject the opinion of two distinct fluids in each sex as perfectly chimerical.

Let us now attend to his account of the formation of the fœtus. The seminal fluids first mix in the uterus, and gradually thicken by the heat of the mother. The mixture extracts the spirit of heat, and, when too warm, part of the heat escapes into the air. But a cold spirit is likewise conveyed to it by the respiration of the mother: thus a cold and a hot spirit alternately

enter the mixture, give life to it, and cover its surface with a pellicle, which assumes a round figure, because the spirits, acting in the centre, expand the matter equally on all sides. I have seen, says the great physician, a fœtus of six days old: it was a ball of liquor inclosed in a pellicle. The liquor was reddish; and the pellicle was interspersed with red and colourless vessels. In the middle of it there was a small eminence, which I apprehended to be the umbilical vessels, by which the fœtus receives nourishment and the spirit of respiration from the mother. A second covering or pellicle gradually forms above the first. Abundance of nourishment is furnished by the menstrual blood, which coagulates by degrees, and is converted into flesh. This flesh gradually articulates as it grows; and the spirit bestows upon it this form. Every part assumes its proper place; the solid particles unite; the moist particles associate by themselves; every thing searches for what is analogous to it; and, in fine, the fœtus, by these causes and means, is completely formed

This system is more rational, and less obscure than that of Aristotle; because Hippocrates endeavours to explain every particular appearance, and borrows one general principle only from the philosophy of his times, namely, that heat and cold produce spirits, and that these spirits have the power of arranging and of bestowing figure upon matter. He treats his subject more like a physician than a philo-

sopher; but Aristotle explains the phænomena of generation more as a metaphysician than a naturalist. It is for this reason that the errors of Hippocrates are particular and less apparent, and that those of Aristotle are general and evident.

These two great men have each had their followers. Almost all the philosophers of the schools adopted Aristotle's theory of generation, while most physicians adhered to the theory of Hippocrates; and, in this manner, seventeen or eighteen centuries passed without the appearance of any thing new upon this mysterious subject.

At last, upon the revival of literature, some anatomists began to investigate the nature of generation; and Fabricius ab Aquapendente was the first who thought of making a course of experiments upon the impregnation and expansion of the eggs of fowls, the substance of which we shall lay before the reader.

He distinguishes the matrix of a hen into two parts, the one superior and the other inferior. The superior part, which he calls the ovarium, is an assemblage of a great number of small yellow eggs, of a round figure, the sizes of which vary from that of a mustard seed to that of a walnut. These eggs are attached to one another by foot-stalks, and the whole somewhat resembles a bunch of grapes. The smallest eggs are white, and they turn yellower in proportion as they increase.

Having examined those yellow eggs immedi-

ately after a communication with the male, he could perceive no sensible difference; he saw none of the male semen in any part of the eggs: he therefore concluded, that the whole eggs, and even the ovarium itself, were rendered fertile by a subtile spirit which issues from the male semen; and, he adds, that, in order to prevent the escape of this fecundating spirit, Nature has placed, at the external orifice of the vagina of birds, a membranous valve, which permits the seminal spirit to enter freely into the vagina, but prevents its return.

When an egg is detached from the common pedicle, it gradually descends, through a winding canal, into an inferior part of the matrix. This canal is filled with a liquor very similar to the white of an egg. It is here that the egg receives its white liquor, the membrane in which it is inclosed, the two cords (*chalazæ*) that run through the white, and join it to the yolk, and the shell which is suddenly formed immediately before exclusion. These cords, according to our author, are the part of the egg which is impregnated by the seminal spirit of the male; and it is here also that the rudiments of the fœtus first appear. The egg is not only the true matrix, or the place where the chick is formed, but the whole business of generation depends upon it. The egg is the great agent in generation; it furnishes both the matter and the organs. The substance of the cords is the matter of which the chick is formed; the white and the yolk afford it nourishment; and the seminal spirit of the

male is the efficient cause. This spirit communicates to the cords, first, an alterant quality, then a forming quality, and, lastly, a power of augmenting, &c.

These observations of Fabricius, it is apparent, lead not to any clear idea of generation. At the same time that this anatomist was making his experiments, which was about the middle of the sixteenth century, the famous Aldrovandus * made some remarks upon eggs. But, as Harvey properly observes of him, he followed more the authority of Aristotle than of experiment. The description he gives of the chick in the egg is by no means exact. Volcher Coiter, one of his pupils, succeeded better than his master; this writer, together with Parisanus, a Venetian physician, have each given descriptions of the chick in the egg, which Harvey prefers to all the others.

This celebrated anatomist, who first discovered the circulation of the blood, has given an excellent treatise on generation. He flourished about the middle of last century, and was physician to Charles I. of England. As he was obliged to follow this unhappy prince during his misfortunes, he lost, among other papers, what he had written concerning the generation of insects; and it appears that he composed from memory his treatise on the generation of birds and of quadrupeds. I shall give a short view of his remarks, of his experiments, and of his theory.

Harvey alleges, that men, and all other ani-

* See his Ornithologia.

mals, proceed from eggs; that, in viviparous animals, the first produce of conception is a kind of egg; and that the only difference between the viviparous and oviparous is, that, in the former, the fœtuses begin to exist, increase, and acquire their full growth in the uterus; but that, in the oviparous animals, the rudiments of the fœtuses begin to exist in the body of the mother, where they are in the form of eggs; and it is only after their exclusion that they become real fœtuses. And it deserves to be remarked, says he, that, in oviparous animals, some retain their eggs till they be perfect, as birds, serpents, and oviparous quadrupeds; and that others exclude their eggs before they are perfect, as fishes, crustaceous and testaceous animals. The eggs laid by these creatures are only the rudiments of eggs, which afterwards acquire membranes and a white, and attract nourishment from the matter with which they are surrounded. There are even, he adds, insects, caterpillars, for example, which are only imperfect eggs; they search for their nourishment; and, at the end of a certain time, they arrive at the state of a chrysalis, which is a perfect egg. Another difference may still be remarked in oviparous animals: the eggs of hens, and other birds, are of all different sizes; but those of fishes, frogs, &c., which lay them before they are perfect, are all of the same size. He indeed observes, that, in pigeons, which lay two eggs, all the small eggs that remain in the ovarium are of the same bulk; and that the two only which are next to be excluded exceed the

size of the rest. The same thing happens in cartilaginous fishes, as in the ray, which only brings to maturity two eggs at a time, all the rest being of different sizes, like those of the hen.

He next describes anatomically the parts necessary to generation; and remarks, that the situation of the anus and vulva in birds differ from those of all other animals, the anus being placed before, and the vulva behind *. And, with regard to the cock and all small birds, he alleges, that they have no proper penis, and that they generate by rubbing, without any intromission. But male ducks, geese, and ostriches, are amply provided with this instrument.

Hens produce eggs without the intervention of the cock; but, though perfect, they are fewer in number and unfertile. He credits not the common opinion, that a few days' intercourse with the cock are sufficient to impregnate all the eggs which a hen will lay during the year; but he acknowledges, that he separated a hen from the cock for twenty days, and that all the eggs she laid were fecundated. As long as the egg remains attached to the ovarium, it is nourished by the vessels of the common pedicle; but, when it separates from this pedicle, it receives the white liquor and the shell from the matter with which the canal of the uterus is filled.

The two cords (*chalazæ*) which Aquapendente considered to be the germ, or part produced by the male semen, are found in unimpregnated,

* Most of these facts are taken from Aristotle.

as well as impregnated eggs; and Harvey properly observes, that these parts neither proceed from the male, nor receive the impregnation. The part of the egg which receives the impregnation is a small white circle situated upon the membrane that covers the yolk, and has the appearance of a cicatrice about the size of a lentil. Harvey likewise remarks, that this cicatrice is found in all eggs, whether they be fecundated or not; and that those are deceived who imagine it to be produced by the seed of the male. It is of the same size and form in fresh eggs as in those which have been long kept. But, as soon as the process of hatching is begun, whether by means of artificial heat, or by the heat of the hen, this small mark or cicatrice gradually augments and dilates, like the pupil of the eye. This is the first change, and it is visible after a few hours' incubation.

When the egg has been heated for twenty-four hours, the yolk, which was formerly in the centre, rises towards the cavity at the thick end of the egg. This cavity continues to enlarge by the evaporation of the more fluid part of the white; and the heaviest part of the white falls down to the small end. The cicatrice or speck on the membrane of the yolk, is elevated along with it, and applies itself to the membrane which lines the cavity at the thick end. This speck is now as large as a pea; and a white point is distinguishable in the middle of it, with several circles, of which this point appears to be the common centre.

At the end of the second day, these circles are larger and more conspicuous, and they divide the speck sometimes into two, and sometimes into three parts, of different colours. A small external protuberance likewise appears, which nearly resembles a little eye, with a white point or cataract on the pupil. Between the circles, a liquor, as transparent as crystal, is contained by means of a very thin membrane. The speck, which is now become a kind of bubble, or liquid globe, appears as if it were situated in the white, rather than on the membrane of the yolk. On the third day the transparent liquor, as well as the membrane in which it is inclosed, is considerably augmented. On the fourth, a small line of blood, of a purple colour, appears on the circumference of the bubble; and, at a little distance from the centre, we perceive a dot or point, of a bloody colour, which beats like a heart. It is visible at every diastole, and disappears during the systole. From this animated point two small blood vessels issue, and terminate in the membrane which contains the transparent crystalline liquor. These blood vessels set off from the same place, nearly in the same manner as the roots of a tree set off from the trunk; and it is in the angle which these roots form with the trunk, and in the middle of the liquor, that the animated point is situated.

Towards the end of the fourth, or beginning of the fifth day, the animated point is so much enlarged, that it has the appearance of a small bladder filled with blood; and, by its contractions

and dilatations, it is alternately filled and emptied. On the same day we distinctly perceive, that this bladder is divided into two parts, each of which dilates and contracts in the same manner. Round the shortest of the blood vessels described above, a kind of cloud appears, which, though transparent, obscures the view of the vessel. Every hour this cloud becomes thicker; it attaches itself to the root of the blood vessel, and seems to depend from it like a small globe. This globe extends, and appears to divide into three parts, one of which is globular, and larger than the other two; and here we perceive the rudiments of two eyes, and of the whole head: and, at the end of the fifth day, we see, in the remainder of this lengthened globe, the beginnings of the vertebræ.

On the sixth day, the parts of the head are more apparent. We distinguish the coats of the eyes, the thighs, and wings; and then the liver, the lungs, and the beak. The fœtus now begins to move and to stretch out its head, though nothing but the viscera are yet formed; for the thorax, the abdomen, and all the external coverings of the fore part of the body, are still wanting. At the end of this day, or the beginning of the seventh, the claws begin to be visible; the chick opens and moves its beak; and the anterior parts of the body begin to cover the viscera. On the seventh day, the chick is entirely formed; and, from this time till it issues from the egg, nothing happens but an expansion of all the parts it acquired during the first seven

days. The feathers appear on the fourteenth or fifteenth day; and, on the twenty-first, the chick escapes from the egg, by breaking the shell with its bill.

These experiments of Harvey appear to have been made with the greatest exactness and fidelity. We shall afterwards, however, demonstrate their imperfection, and that the author has probably fallen into the common error of making experiments, with a view to establish his favourite hypothesis, that the first animated point which appeared was the heart. But, before proceeding to this object, it is proper to give an account of his other experiments.

Every body knows the numerous experiments made by Harvey upon female deer. They receive the male about the middle of September. A few days after copulation, the *horns** of the uterus appear to be thicker and more fleshy than usual: they are, at the same time, more lax and flabby; and, in each of their cavities, five carunculæ, or soft warts, appear. About the 26th or 28th of September, the uterus is still thicker; the five carunculæ are swelled nearly to the size and form of a nurse's nipple. On opening them with a scalpel, they appeared to be filled with an infinite number of white points. Harvey pretends to have remarked, that, neither now, nor

* Two fleshy processes, one of which issues from each side of the *fundus uteri*, in the form of little *horns*, and are remarkably large in some quadrupeds.

immediately after copulation, had the ovarium suffered any change; and that he never could discover, after repeated trials, the least drop of male semen in the uterus.

Towards the end of October, or the beginning of November, when the females were separated from the males, the thickness of the *horns* began to diminish; the internal surfaces of their cavities were swelled, and seemed to be glued together. The carunculæ still remained; and the whole resembled the substance of the brain, being so soft that it could not be touched. Harvey tells us, that, on the 13th or 14th of November, he perceived filaments, like those of a spider's web, which traversed the cavities of the *horns*, and even that of the uterus itself. These filaments arose from the superior angle of the *horns*, and, by their number, formed a kind of membrane or empty coat. A day or two afterwards, this coat or sac was filled with a white, aqueous, viscid matter, and adhered to the uterus by means of a kind of mucilage; and the adhesion was most sensible at the superior part of the uterus, where the rudiments of the placenta began then to appear. In the third month, this sac contained an embryo of two fingers' breadth in length, and also an internal sac, called the amnios, inclosing a transparent crystalline liquor, in which the fœtus swam. The fœtus, at first, was only an animated point, like what appeared in the hen's egg. Every thing now proceeded and terminated in the same manner as described with regard to the

chick, with this only difference, that the eyes of the chick appeared much sooner than those of the deer. The animated point was visible about the 19th or 20th of November. A day or two afterwards, the oblong body, which contained the rudiments of the fœtus, made its appearance. In six or seven days more, the fœtus was so completely formed, that all its members, and even its sex, were distinguishable. But the heart and viscera were still bare; and it was not till a day or two after, that they were covered with the integuments of the abdomen and thorax. This is the last work, the slating of the edifice.

From these experiments upon hens and deer, Harvey concludes, that all female animals have eggs; that in these eggs a separation of a transparent crystalline liquor, contained in a sac *(amnios)*, takes place, and that another external sac *(chorion)* incloses the whole liquors of the egg; that the first thing which appears in the crystalline liquor is an animated sanguineous point; and, finally, that the formation of viviparous animals is effected in the same manner as that of the oviparous: the following is the account which he gives of the generation of both.

Generation, he observes, is an operation of the uterus alone; for not a drop of the male semen ever enters it. The uterus conceives by a kind of contagion, communicated to it by the semen of the male nearly in the same manner as the loadstone communicates a magnetic virtue to iron. This male contagion acts not only on the

uterus, but on the whole body of the female, which is entirely fecundated, though the uterus alone possesses the faculty of conception, in the same manner as the brain has the sole power of conceiving ideas. The ideas conceived by the brain are similar to the images of the objects transmitted to it by the senses; and the fœtus, which may be regarded as the idea of the uterus, is similar to that by which it is produced. This is the reason why children resemble their fathers, &c.

I will follow the system of our anatomist no farther: what has been said is sufficient to enable the reader to form a judgment. But we have remarks of importance to make concerning his experiments. He has represented them in a manner the most plausible and insinuating. He appears to have repeated them often, and to have taken every necessary precaution to avoid fallacy and deception; and, of course, we are led to think that he has seen every thing which possibly could be discovered. Uncertainty and obscurity, however, are perceptible in his descriptions. His observations are related from memory; and he seems, though he often maintains the contrary, to have made Aristotle, more than experience, his guide; for he has seen every thing in eggs, and very little more than was mentioned by that philosopher. That the most material of his observations were made long before his own time, we shall be convinced by attending to what follows:

Aristotle knew, that the cords (*chalazæ*) in

eggs were of no use in the generation of the chick: "Quæ ad principium lutei grandines hærent, nil conferunt ad generationem, ut quidam suspicantur *." Parisanus, Volcher Coiter, Aquapendente, &c., had remarked the small cicatrice as well as Harvey. Aquapendente believed it to be of no use; but Parisanus maintained that it was formed by the male semen, or, at least, that the white point in the middle of the cicatrice was the semen of the male, and that it was the rudiments of the fœtus. "Estque," says he, "illud galli semen alba et tenuissima tunica abductum, quod substat duabus communibus toti ovo membranis," &c. Hence the only discovery proper to Harvey consists in his remarking the existence of this cicatrice, both in fecundated and unfecundated eggs; for the other writers had observed, as well as he, the dilatation of the circles, and the growth of the white point. These are all the remarks Harvey has made in his account of the two first days of incubation; what he mentions concerning the third day is a repetition only of what Aristotle delivers in the sixth book and fourth chapter of his History of Animals: "Per id tempus ascendit jam vitellus ad superiorem partem ovi acutiorem, ubi et principium ovi est et fœtus excluditur; corque ipsum apparet in albumine sanguinei puncti, quod punctum salit et movet sese instar quasi animatum; ab eo meatus venarum specie duo, sanguine pleni, flexuosi, qui,

* Hist. Anim. lib. vi. cap. 2.

crescente fœtu, feruntur in utramque tunicam ambientem, ac membrana sanguineas fibras habens eo tempore albumen continet sub meatibus illis venarum similibus; ac paulo post discernitur corpus pusillum initio, omnino et candidum, capite conspicuo, atque in eo oculis maxime turgidis qui diu sic permanent, sero enim parvi fiunt ac considunt. In parte autem corporis inferiore nullum extat membrum per initia, quod respondeat superioribus. Meatus autem illi qui a corde prodeunt, alter ad circumdantem membranam tendit, alter ad luteum, officio umbilici."

Harvey, because Aristotle says that the yolk rises to the small end of the egg, concludes that he had seen nothing himself, but that he had received his information from some other pretty accurate observer. In this accusation, Harvey evidently injures Aristotle; for the rising of the yolk to either end, depends solely upon its position during the time of incubation; for the yolk, being lighter than the white, uniformly mounts to the top, whether the large or the small end of the egg be uppermost. This observation we owe to William Langley, a physician in Dordrecht, who made experiments on the hatching of eggs in the year 1655, about twenty years before Harvey's time *.

But, to return to the passage we have quoted. It is apparent that the crystalline liquor, the

* See Langley Observ. editæ a Justo Schradero, Amst. 1764.

animated point, the two circles, the two blood vessels, &c., are described by Aristotle in the same manner as they were seen by Harvey. This anatomist maintains, that the animated point is the heart, that the heart is the first part of the fœtus which is formed, and that the viscera and other members succeed. All these circumstances have been mentioned by Aristotle, and seen by Harvey; and yet that the heart is first formed is by no means consonant to truth. To be assured of this fact, we have only to repeat the same experiments, or to read with attention those of Malpighius *, which were made about fifty years after the trials of Harvey.

Malpighius carefully examined the cicatrice, which is the essential part of the egg; he found that it was large in impregnated eggs, and small in those which had received no impregnation; and he discovered, that, in eggs which had never been sat upon by the hen, the white point, mentioned by Harvey as the first part that becomes animated, is a small purse or bubble swimming in the liquor bounded by the first circle; and that the embryo is visible in the centre of this purse. The membrane of the purse, which is the amnios, being exceedingly thin and transparent, allowed him to see the fœtus distinctly. Malpighius, from this first observation, concludes with propriety, that the fœtus exists in the egg before incubation, and that the rudiments of the embryo are even then deeply rooted. It is un-

* Malpighii pullus in ovo.

necessary to mention how much this experiment differs from the opinion of Harvey; for he had observed nothing formed during the two first days of incubation; and, in his estimation, the first vestige of a fœtus is the animated point, which appears not till the third day. But Malpighius discovered that the rudiments of the whole fœtus exist before incubation is commenced.

After ascertaining this important fact, Malpighius proceeded to examine the cicatrice of unimpregnated eggs, which, as formerly remarked, is smaller than in those that have received an impregnation. Its margin is often irregular, and its texture sometimes differs in different eggs. Near its centre, in place of a bubble including the fœtus, there is a globular mole, or unorganized mass, which, when opened, presents nothing like regularity or arrangement of parts: it has only some appendages filled with a thick but transparent liquor; and this unformed mass is surrounded and enveloped in several concentric circles.

After six hours' incubation the cicatrice is considerably enlarged; and, in its centre, a bubble or globule, formed by the amnios, is easily distinguishable. This globule is filled with a fluid, in the middle of which the head and back bone of the chick visibly appear. Six hours after, every thing is enlarged, and, of course, more apparent to the eye. In six hours more, that is, eighteen hours after the commencement of incubation, the head is larger, and the spine is lengthened; and at the end of twenty-four hours,

the head of the chick appears in a bended posture, and the spine is of a whitish colour. The vertebræ are ranged on each side of the spine, like small globules; and nearly at the same time, the wings begin to sprout, and the head, neck, and breast, are lengthened. At the end of thirty hours, nothing new appears; but all the parts are enlarged, and especially the amnios. Round this membrane may be remarked the umbilical vessels, which are of a dark colour. In thirty-eight hours, the chick has acquired more strength; its head is very large, and three vesicles appear in it surrounded with membranes, which likewise include the spine of the back; through which, however, the vertebræ are still visible. At the end of forty hours, it was admirable to observe, continues our author, the chick living in the centre of the liquor of the amnios. The back bone was increased, the head was bended, the vesicles of the brain were less bare, the rudiments of the eyes appeared, the heart beat, and the blood circulated. Here Malpighius describes vessels and the circulation of the blood; and he thought, with reason, that, though the heart did not beat till thirty-eight or forty hours after incubation was begun, it nevertheless existed before, as well as the other parts of the chick. But, on examining the heart in a dark chamber, he observed nothing like luminous sparks issuing from it, as Harvey seems to insinuate.

At the end of the second day, the fœtus appeared swimming in the liquor of the amnios. The head, which seemed to be composed of ve-

sicles, was bended; the back bone and vertebræ were lengthened; the heart, which hung out of the breast, beat three times successively, because the fluid it contains is pushed from the auricle into the ventricles, from the ventricles into the arteries, and, lastly, into the umbilical vessels. He remarks, that, having separated the chick from the white of the egg, the motion of the heart continued for a whole day. In fourteen hours more, or sixty-two hours from the beginning of incubation, the chick, though stronger, remained still with its head bended in the liquor of the amnios. Veins and arteries were perceived in the brain; and the lineaments of the eyes, and of the spinal marrow, appeared. At the end of three days, the body of the chick was crooked. Beside the two eyes, five vesicles filled with liquor appeared in the head; the rudiments of the thighs and of the wings were discernible; the body began to take on flesh; and the pupils of the eyes, and likewise the crystalline and vitreous humours, were distinguishable. At the termination of the fourth day, the vesicles of the brain were nearer each other; the processes of the vertebræ were longer; the wings and thighs had become stronger, in proportion as they grew longer; the whole body was covered with an unctuous flesh; the umbilical vessels had pierced through the abdomen; and the heart was concealed within the breast, which was now shut up by a thin membrane. On the fifth, and at the end of the sixth day, the vesicles of the brain began to be covered;

the spinal marrow, which was now more solid, was divided into two parts, and advanced along the trunk; the thighs and wings were longer; and the wings were unfolded; the abdomen was shut and tumified; the liver was distinctly visible; and it was of a dark colour; the two ventricles of the heart beat; the body of the chick was covered with skin; and the points of the feathers began to appear. On the seventh day, the head was very large; the brain was covered with its membranes; the beak appeared between the two eyes; the wings, the thighs, and the legs, had acquired their perfect form; the heart seemed to be composed of two ventricles, like two contiguous globules, united at their superior part with the auricles; and two successive pulses were remarked both in the ventricles and auricles, as if there had been two separate hearts.

But I will follow Malpighius no farther. The remainder of the detail regards the growth and perfection of the parts till the chick breaks the shell in which it is inclosed, and becomes an inhabitant of a new world. The heart is the last part that assumes its proper figure, by the union of its ventricles, which happens not till the eleventh day.

We are now in a condition to form a distinct judgment concerning the value of Harvey's experiments. It is probable that this celebrated anatomist did not make use of the microscope (which was, indeed, very imperfectly known in his days), otherwise he never would have affirmed, that there was no difference between

the cicatrice of impregnated and unimpregnated eggs; he never would have said, that the semen of the male produced no change upon the egg, and particularly upon the cicatrice; he never would have advanced, that nothing was perceptible before the end of the third day; that the animated point appeared first; and that the white point was transformed into the animated point: he would have perceived that the white point was the bubble or globule which contained the whole apparatus of generation; and that all the rudiments of the fœtus commenced there from the moment of receiving the impregnation of the cock: he would likewise have discovered, that, without this impregnation, it contains nothing but an unformed mass, which could never become animated; because, in fact, it is not organized like an animal, and because it is only after this mass, which ought to be regarded as a collection of the organic particles of the female semen, is penetrated by the organic particles of the male semen, that an animal is formed. This formation is instantaneous; but the motions of the new animal are imperceptible till forty hours after the process of incubation has commenced: he would not have assured us that the heart is first formed, and that the other parts are successively joined to it by juxta-position; since it is apparent, from the experiments of Malpighius, that the rudiments of all the parts are formed at once, but that they become perceptible only in proportion as they are successively unfolded: lastly, if he had seen, as Malpighius saw, he

would not have positively asserted, that no impression of the male seed remained in the eggs, and that it was only by contagion that they were impregnated, &c.

It is likewise proper to remark, that what Harvey has said concerning the parts of generation of the cock is by no means exact. He affirms that the cock has no penis capable of entering the vagina of the hen. It is certain, however, that this animal, in place of one penis, has a couple, which both act at the same time: and this action is a vigorous compression, if not an actual copulation*. It is by this double organ that the cock throws his seminal liquor into the uterus of the hen.

Let us now compare Harvey's experiments upon female deer with those of de Graaff upon female rabbits; and, though de Graaff believed, as Harvey did, that all animals proceed from eggs, we shall find a great difference in the manner in which these two anatomists have perceived the first formation, or rather the expansion of the fœtuses of viviparous animals.

After exerting every effort to prove, by arguments drawn from comparative anatomy, that the testicles of viviparous females are true ovaria, Graaff explains the manner in which the eggs are detached from the ovaria, and fall into the horns of the uterus. He then relates the remarks he made upon a rabbit which he dissected half an hour after copulation. The horns

* See Regn. Graaff, p. 242.

of the uterus, he says, were uncommonly red; there was no change either in the ovaria, or in the eggs which they contained; and there was not the least appearance of semen in the vagina, in the uterus, or in the *Fallopian tubes*.

Having dissected another rabbit, six hours after copulation, he observed, that the follicles, or coats, which, in his estimation, contain the eggs in the ovarium, were become red; but he found no male semen either in the ovaria or any where else. Twenty hours after copulation, he dissected a third: he remarked in one ovarium three, and in the other five follicles much altered; for instead of being clear and limpid, they had become opaque and reddish. In another, dissected twenty-seven hours after copulation, the horns of the uterus, and the superior canals which terminate in them, were still more red; and their extremities embraced the ovarium on all sides. In another, which was opened forty hours after copulation, he found in one ovarium seven, and in the other three follicles changed. Fifty-two hours after copulation, he examined another, and found in one ovarium four changed follicles, and one in the other; and, having opened these follicles, he discovered in them a kind of glandulous liquor, with a small cavity in the middle, where he could perceive no fluid, which made him suspect that the transparent liquor usually contained in the follicles, and which, he says, is inclosed in its own membranes, might have been discharged by some kind of rupture. He searched for this matter in the canals which

terminate in the horns of the uterus, and in the horns themselves; but he found nothing. He only remarked, that the membranes which line the horns of the uterus were much swelled. In another rabbit, dissected three days after copulation, he observed, that the superior extremity of the canal, which terminates in the horns of the uterus, straitly embraced the ovarium on every side: and, having separated it from the ovarium, he remarked, in the right ovarium, three follicles, somewhat larger and harder than usual. After searching, with great care, the canals above mentioned, he discovered, he says, an egg in the right canal, and two more in the right horn of the uterus, so small that they exceeded not mustard seeds. These little eggs had each two membranes, and the internal one was filled with a very limpid liquor. Having examined the other ovarium, he found four changed follicles; three of them were whiter, and had likewise some limpid liquor in their centres; but the fourth was of a darker colour, and contained no liquor, which made him suspect that the egg had escaped. He therefore searched the corresponding canal and horn of the uterus; he found an egg in the superior extremity of the horn, which was exactly similar to those he had discovered in the right horn. He alleges, that the eggs, when they are separated from the ovarium, are ten times less than before their separation; and this difference in size, he imagines, is owing to the eggs, while in the ovarium, containing another matter.

namely, the glandulous liquor which he remarked in the follicles.

Four days after copulation, he opened another rabbit, and found in one ovarium four, and in the other three follicles, void of eggs: in the horns corresponding to the ovaria, he found four eggs on one side, and three in the other. These eggs were larger than those he had discovered three days after copulation. They were nearly of the size of the lead shot used for shooting small birds; and he remarked, that, in these eggs, the interior membrane was separated from the exterior, and appeared as if a second egg was contained within the first. In another, dissected five days after copulation, he found five empty follicles in the ovaria, and an equal number of eggs in the uterus, to which they adhered very firmly. These eggs were as large as the shot employed for killing hares; and the internal membrane was still more apparent than in the last experiment. Having opened another rabbit, six days after copulation, he found in one of the ovaria six empty follicles, but only five eggs in the corresponding horn of the uterus; and they seemed to be all accumulated into one mass: in the other ovarium, he saw four empty follicles, and found but one egg in the corresponding horn. These eggs were of the size of the largest fowling shot. Seven days after copulation, our anatomist opened another rabbit, and he found in the ovaria some empty follicles, which were larger, harder, and more red

than those he had formerly observed; and he perceived as many transparent tumors in different parts of the uterus; and, having opened them, he took out the eggs, which were as large as small *pistol* bullets. The internal membrane was more distinct than formerly; and within this membrane he saw nothing but a very clear liquor. In another, dissected eight days after copulation, he found in the uterus the tumors or cells which contain the egg; but they adhered so strongly to the uterus, that he could not detach them. In another, which he opened nine days after copulation, he found the cells containing the eggs greatly enlarged; and he perceived, in the middle of the liquor inclosed by the internal membrane, a small thin cloud. In another, which he opened ten days after copulation, the small cloud was thicker and darker, and formed an oblong body like a little worm. Lastly, twelve days after copulation, he distinctly perceived the embryo, which, though two days before it was only an oblong body, was now so apparent, that he could distinguish its different members. In the region of the breast, he saw two red and two white points, and, in the abdomen, a mucilaginous reddish substance. Fourteen days after copulation, the head of the fœtus was large and transparent; the eyes were prominent; the mouth was open; the rudiments of the ears appeared; the back bone was whitish, and bended towards the sternum; and small blood vessels arose from each side of it, the ra-

mifications of which extended along the back as far as the legs: the two red points were considerably enlarged, and appeared like the rudiments of the ventricles of the heart; on each side of the red points he saw two white ones, which were the rudiments of the lungs. In the abdomen he saw the rudiments of the liver, which was reddish, and a small body twisted like a thread, which was the stomach and intestines. After this, till the 31st day, when the female rabbit brings forth, there was nothing to be remarked but the gradual expansion and growth of the parts which were already formed.

From these experiments, De Graaf concludes, that all viviparous females have eggs; that these eggs are contained in the ovaria or testicles; that they cannot be separated till they are fecundated by the semen of the male; because, says he, the glandulous liquor, by means of which the eggs are enabled to escape from their follicles, is not secreted till after an impregnation by the male. He alleges, that those who imagine they have seen pretty large eggs in three days, have been deceived; because, in his opinion, the eggs, though fecundated, remain longer in the ovarium, and, in place of augmenting, they become ten times less than formerly, and they never begin to grow till after their descent from the ovaria into the uterus.

By comparing these observations of De Graaff with those of Harvey, we will easily perceive that the latter has missed the principal facts: and,

though there are several errors both in the reasoning and in the experiments of De Graaff, this anatomist, as well as Malpighius, have discovered themselves to be better observers than Harvey. They agree in all fundamental points, and both of them contradict Harvey. He perceived not the alterations which take place in the ovaria; he saw not in the uterus those small globules which contain the materials of generation, and which are called eggs by De Graaff. He never suspected that the fœtus existed in the egg; and, though his experiments give us tolerably exact ideas concerning what happens during the growth of the fœtus, he furnishes no information concerning the commencement of fecundation, nor concerning the first expansion of the fœtus. Schrader, a Dutch physician, who had a great veneration for Harvey, acknowledges that he cannot be trusted in many articles, and particularly in what relates to the first formation of the embryo; for the chick really exists in the egg before incubation; and, he says, that Joseph of Aromatarius was the first who made this material observation *. Besides, though Harvey alleged that all animals proceeded from eggs, he never imagined that the testicles of females contained eggs; and it was only from a comparison between the sac, which he believed to be formed in the uterus of viviparous animals, with the growth and covering of the eggs in oviparous animals, that he maintained that all

* See Obj. Justi Schraderi, Amst. 1674.

animals were produced from eggs; and even this is but a repetition of what Aristotle had said before him. Steno was the first who pretended to have discovered eggs in the ovaria of females. He says, that, in dissecting a female sea dog, he perceived eggs in the testicles, though this animal be viviparous; and he adds, that the testicles of women are analogous to the ovaria of oviparous animals, whether the eggs themselves fall into the uterus, or only the matter which they contain. Steno first discovered these supposed eggs; De Graaff is willing to assume the discovery to himself; and Swammerdam warmly disputes the point with him, and alleges that Van Horn had seen them before De Graaff. This last writer, it is true, has been accused of asserting many things which have been contradicted by experiments: he even pretended, that a certain judgment might be formed of the number of fœtuses in the uterus, by the number of cicatrices or empty follicles in the ovaria. In this he is contradicted by the experiments of Verrheyen *, by those of M. Mery †, and by some of his own, where he found fewer eggs in the uterus, than cicatrices in the ovaria. Besides, we shall demonstrate that what he says concerning the separation of the eggs, and the manner in which they descend into the uterus, is by no means exact; that no eggs exist in the testicles of females; that what is seen in the uterus is not an egg; and that

* *Tom. ii. chap. 3, edit. De Bruxelles, 1710.*

† Hist. de l'Acad. 1701.

the systems which have been deduced from the observations of this celebrated anatomist are perfectly chimerical.

This pretended discovery of eggs in the testicles of females attracted the attention of most anatomists. They only found, however, in the testicles of viviparous females, small bladders. These they hesitated not to consider as real eggs; and, therefore, they called the testicles *ovaria*, and the vesicles *eggs*. They asserted also, like De Graaff, that these eggs differed in size in the same ovarium; that the largest in the ovaria of women exceeded not the bulk of a small pea; that they are very small in young girls; but that they increased with age and intercourse with men; that not above twenty could be reckoned in each ovarium; that these eggs are fecundated in the ovarium by the spirituous part of the male semen; that they then separate and fall into the uterus through the Fallopian tubes, where the fœtus is formed of the internal substance of the egg, and the placenta of its external parts; that the glandulous matter, which exists not in the ovarium till after a fruitful embrace, compresses the egg, and excludes it from the ovarium, &c. But, though Malpighius, who examined more accurately, detected many errors committed by these anatomists, even before they were received; yet most physicians adopted the opinion of De Graaff, without regarding the observations of Malpighius, which were nevertheless of the greatest importance, and which received much

weight from the experiments of his disciple Valisnieri.

Malpighius and Valisnieri, of all naturalists, appear to have written with most judgment and acuteness on the subject of generation. We shall, therefore, give an account of their experiments and remarks.

Malpighius, after examining the testicles of a number of cows and other female animals, assures us, that he found, in the testicles of all of them, vesicles of different sizes, whether the females were very young or adults. These vesicles are enveloped in a pretty thick membrane, the inside of which is interspersed with blood vessels; and they are filled with a kind of lymph or liquor, which coagulates and hardens by the heat of a fire like the white of an egg.

In process of time, a firm yellow body adheres to the testicles. It is prominent, increases to the size of a cherry, and occupies the greatest part of the ovarium. This body consists of several angular lobes, the position of which is very irregular, and it is covered with a coat or membrane interspersed with nerves and blood vessels. The form and appearance of this yellow body varies considerably at different times. When it exceeds not the size of a grain of millet, it is roundish, and its substance, when cut, has a warty appearance. We often find an external covering round the vesicles of the ovaria, which consists of the same substance with the yellow bodies.

When the yellow body has become nearly of the size of a pea, it resembles a pear; and, in the centre of it, there is a small cavity filled with liquor. The same thing may be remarked when it is as large as a cherry. In some of these yellow bodies, after they have arrived at full maturity, Malpighius affirms that he saw, towards the centre, a small egg with its appendages, about the size of a millet seed; and, after they had discharged these eggs, they were flaccid and empty. They then resembled a cavernous canal; and the void cavities were as large as peas. He conceived that Nature designed this yellow glandulous body for the preservation of the egg, and for making it escape from the testicles; and that, perhaps, it contributed to the formation of the egg: consequently, he remarks, the vesicles which are at all times found in the ovarium, and always differ in size, are not the true eggs which receive the impregnation, but serve only to produce the yellow bodies in which the eggs are formed. Besides, though these yellow bodies are not always found in every ovarium; yet we always find the rudiments of them. Malpighius found the marks of them in new born heifers, in cows with calf, and in pregnant women; and, therefore, he properly concludes, that these yellow glandulous bodies are not, as De Graaff asserts, an effect of impregnation. The yellow bodies, he remarks, produce unfecundated eggs, which fall out of the ovarium independent of any communication with the male, and also those

which fall after impregnation. When the impregnated eggs fall into the uterus, every thing proceeds in the manner described by De Graaff.

These observations of Malpighius demonstrate, that the testicles of females are not real ovaria; that the vesicles they contain are not eggs; that these vesicles never fall into the uterus; and that the testicles, like those of males, are only reservoirs, containing a liquor which may be regarded as female semen in an imperfect state. This semen is matured in the yellow glandulous bodies, of which it fills the internal cavities, and flows out after the yellow bodies have acquired their full size.

But, before we form a judgment concerning this important point, we must attend to the remarks of Valisnieri.

In the year 1692, Valisnieri began his experiments upon the testicles of the sow. The testicles of the sow differ from those of cows, of mares, of sheep, of she asses, of female dogs, of she goats, of women, and of most viviparous animals; for they resemble a small bunch of raisins, the grains of which are round and prominent on the outside; between these grains are smaller ones, which have not acquired full maturity. These grains appear not to be covered with a common membrane. They are, says he, analogous to the yellow bodies observed in cows by Malpighius; they are round, and of a reddish colour; their surface is interspersed with blood vessels, like the eggs of viviparous animals; and

the whole grains together form a mass which is larger than the ovarium. With a little address, these grains may be separated from the ovarium, and each of them, after separation, leaves a nitch or depression.

These glandulous bodies are not of the same colour. In some sows they are more red; in others more clear; and they are of all sizes, from the smallest seed to that of a raisin. On opening them, a triangular cavity appears, filled with a limpid liquor, which coagulates with heat, and becomes white, like that which is contained in the vesicles. Valisnieri expected to find the egg in some of these cavities, but in this he was disappointed; though he made a careful search into all the glandulous bodies of a number of sows, and other animals, he could never discover the egg, which Malpighius affirms he once or twice found.

Under these glandulous bodies, the vesicles of the ovarium appeared. They were more or less numerous, according as the glandulous bodies were larger or smaller; for, in proportion to the largeness of the glandulous bodies, the vesicles diminished. Some vesicles were of the size of a lentil, and others exceeded not that of a millet seed. In the testicles, when raw, from twenty to thirty-five vesicles might be reckoned; but when boiled, a much greater number appear, and they are so firmly attached, that they cannot be separated without breaking some of them.

Having examined the testicles of a young

sow, which had never brought forth, he found, as in the others, the glandulous bodies; and their triangular cavities were likewise filled with lymph; but he could not discover any eggs, either in the one or the other. The vesicles of this young sow were more numerous than in those which had brought forth, or those which were impregnated at the time of examination. In the testicles of another sow, which was far advanced in pregnancy, Valisnieri found two of the largest glandulous bodies, which were flaccid and empty, and others, of a lesser size, in their ordinary state; and, in several others, which he dissected when with young, he remarked that the number of glandulous bodies was always greater than the number of fœtuses. This fact confirms what we observed concerning the experiments of De Graaff, and proves that they are by no means exact. What he calls follicles of the ovarium are only the glandulous bodies, the number of which always exceeds that of the fœtuses. In the ovaria of a sow, two or three months old, the testicles were pretty large, and interspersed with vesicles of a considerable size. Among the vesicles, the beginnings of four glandulous bodies appeared in one testicle, and of seven in the other.

After these experiments upon sows, Valisnieri repeats those of Malpighius upon cows, and he found them to be exactly conformable to truth. He indeed acknowledges, that he was never able to discover the egg which Malpighius imagined he had seen once or twice in the interior

cavities of the glandulous bodies. After a fruitless search in the testicles of so many different females, it was natural to think that Valisnieri would at least have doubted the existence of such eggs. But prejudice in favour of system made him admit, contrary to his own experience, the existence of eggs, which neither he nor any other man ever saw, or ever will see.

It is, perhaps, impossible to make a greater number, or more exact experiments, than those of Valisnieri. Among other animals he examined the ewe, and found that she never has more glandulous bodies in her testicles than fœtuses in the uterus. In young ewes, which were never impregnated, there is but one glandulous body in each testicle, and when one is emptied it is succeeded by another; if a ewe has one fœtus in the uterus, she has only one glandulous body in her testicles; and if she has two fœtuses, she has likewise two glandulous bodies. This glandulous body occupies the greatest part of the testicle; and, after it is emptied and disappears, another begins to grow for the purpose of a future generation.

In the testicles of a she ass, he found vesicles as large as small cherries; which is an evident proof that they are not eggs, as it would be impossible for them to pass, by the Fallopian tubes, into the uterus.

The testicles of female wolves, dogs, and foxes, are covered with a membrane, like a purse, which is an expansion of that which surrounds the horns of the uterus. In a bitch which began

to be in season, but had not been approached by the male, Valisnieri found the internal part of this purse, which does not adhere to the testicle, moistened with a liquor that resembled whey, and two glandulous bodies in the right testicle, about two lines in diameter, and which occupied nearly the whole extent of the testicle. Each glandulous body had a small nipple, with a distinct fissure, from which, without pressing it, there issued a liquor like clear whey; he therefore concluded that this liquor was the same which he found in the purse. He blew into this fissure with a pipe, and the whole glandulous body immediately swelled; and, having introduced a bristle, he easily penetrated to its bottom. He opened the body on that side where he had introduced the bristle, and found an internal cavity, which communicated with the nipple, and contained a considerable quantity of liquor. Valisnieri was always in hopes of discovering the egg; but these hopes, notwithstanding all his researches, were uniformly frustrated.

He likewise found in the left testicle two glandulous bodies very similar to those in the right. He boiled two of these glandulous bodies, hoping that, by this means, he might discover the egg; but still without any measure of success.

Having dissected another bitch four or five days after she had received the male, he found in the testicles three glandulous bodies, exactly similar to the former. He searched every where for the egg; but he was still disappointed. By the assistance of the microscope, he discovered

the glandulous bodies to be a net-work, composed of an infinite number of globular vesicles, which served to filtre the liquor that issued through the nipple.

He then opened another bitch, which was not in season; and, having tried to introduce air between the testicle and the purse which covered it, he found that it dilated like a bladder filled with air. Having removed the purse, he discovered two glandulous bodies upon the testicles; but they had neither nipple nor fissure, and no liquor distilled from them.

In another bitch, that had brought forth about five whelps two months before, he found five glandulous bodies; but they were much diminished in size, and they began to disappear, without leaving any cicatrices. There remained only a small cavity in their centre; but it contained no liquor.

Not satisfied with these and many other experiments, Valisnieri, who passionately desired to discover this pretended egg, called together the best anatomists his country afforded, and, among others, M. Morgagni; and, having opened a young bitch, that was for the first time in season, and that had been covered three days before, they examined the vesicles of the testicles, the glandulous bodies with their nipples, their canals, and the liquor in their internal cavities; but they could perceive no eggs. He then, with the same intention, made experiments on she goats, foxes, cats, a number of mice, &c. In the testicles of all these animals, he uniformly

found the vesicles, and frequently the glandulous bodies, with the liquor they contained; but no egg ever appeared.

In fine, being desirous of examining the testicles of women, he had an opportunity of opening a young countrywoman, who had been some years married, and who was killed by a fall from a tree. Though of a robust and vigorous constitution, she had never born any children. He endeavoured to discover if the cause of her barrenness existed in the testicles; and he found that the vesicles were all filled with a blackish and corrupted matter.

In a young girl of eighteen years of age, who had been brought up in a convent, and who had every appearance of real virginity, he found the right testicle a little longer than the left: it was of an oval figure, and its surface was somewhat unequal. This inequality was occasioned by five or six vesicles which protruded on the outside of the testicle. One of these vesicles, which was more prominent than the rest, he opened, and a quantity of lymph rushed out. This vesicle was surrounded with a glandulous substance, in the shape of a crescent, and of a reddish yellow colour. He cut the testicle transversely, and found a number of vesicles filled with limpid liquor; and he remarked, that the Fallopian tube of this testicle was redder and somewhat longer than the other, as he had often observed in other animals when they were in season.

The left testicle was whiter, and its surface more smooth; for, though some vesicles were a

little prominent, none of them were in the form of nipples; they were all similar to each other, and the corresponding Fallopian tube was neither swelled nor red.

In the body of a girl, aged five years, he found the testicles, with their vesicles, their blood vessels, and their nerves.

In the testicles of a woman of sixty years, he discovered some vesicles, and the vestiges of a glandulous substance, like large points of an obscure yellowish brown colour.

From all these observations, Valisnieri concludes, that the work of generation is carried on in the female testicles, which he continued to regard as ovaria, though he never could find any eggs in them, and though, on the contrary, he had discovered that the vesicles were not eggs. He says, likewise, that, for the impregnation of the egg, it is not necessary that the male semen should enter the uterus. He supposes, that the egg escapes through the nipple of the glandulous body, after being impregnated in the ovarium; that it then falls into the Fallopian tube; that it gradually descends, and at last attaches itself to the uterus: he adds, that he is fully persuaded that the egg is concealed in the cavity of the glandulous body, though neither he nor any other anatomist was ever able to discover it.

In his estimation, the spirit of the male seed ascends into the ovarium, penetrates the egg, and gives motion to the fœtus, which previously existed in the egg. In the ovarium of the original mother of mankind, he observes, were eggs,

which contained not only all the children she produced, but of the whole human race. If this chain of infinite individuals contained in one be incomprehensible to us, it is entirely owing to the imbecility of our minds, of which we have daily proofs. But it is not, therefore, less consonant to truth, that all the animals which have existed, or can exist, were created at once, and were all included in their first mothers. The resemblance of children to their parents is owing, he continues, to the imagination, which acts so forcibly on the fœtus as to produce stains, monstrosities, disorder of parts, and extraordinary concretions, as well as perfect similarities.

This system of eggs, though it explains nothing, and has no foundation in nature, would have obtained the universal suffrages of physicians, if, nearly about the same time, another opinion had not sprung up, founded upon the discovery of spermatic animals.

This discovery, which we owe to Leeuwenhoek and Hartsoeker, was confirmed by Andry, Valisnieri, Bourguet, and many other observers. I shall relate what has been advanced concerning those spermatic animals which are found in the semen of all males. Their number is so great, that the semen seems to be entirely composed of them; and Leeuwenhoek pretends to have seen many millions of them in a drop less than the smallest grain of sand. Though none of them appear in females, they are found in the emitted semen of all males, in the testicles, and in the vesiculæ seminales. When the semen of

a man is exposed to a moderate heat, it thickens, and the motion of all the animalcules is suddenly stopped. But, when allowed to cool, it dilutes, and the animals continue in motion till the liquor again thickens by evaporating. The more this fluid is diluted, the number of animalcules is augmented; and, when greatly diluted by the addition of water, the whole substance of the fluid seems to be composed of animals. When the motion of the animalcules is about to cease, either on account of heat or of drying, they appear to approach nearer each other, to have a common circular motion in the centre of the small drop under observation, and to perish, all of them, at the same instant. But, when the quantity of liquor is greater, it is easy to distinguish them dying in succession.

These animalcules are said to be of different figures in different animals; but they are all long, thin, without any members, and move with rapidity in every direction. The fluid in which they are contained, as formerly remarked, is much heavier than blood. The semen of a bull, when chemically analyzed by Verrheyen, yielded first phlegm, then a considerable quantity of fetid oil, a very small proportion of volatile salt, and more earth than he expected *. This author was surprised that he could draw no spirit from the distillation of semen; and, as he imagined it contained a great quantity of spirits, he attributed the evaporation of them to

* See Verrheyen sup. Anat. tom. ii. p. 69.

their subtilty. But may we not suppose, with more probability, that it contains little or no spirits? Neither the consistence, nor the odour of this fluid, indicate the presence of ardent spirits, which never abound but in fermented liquors; and, with regard to volatile spirits, the horns, bones, and solid parts of animals, afford more of them than the fluids. What has received the appellation of seminal spirits, *aura seminalis,* among anatomists, has, perhaps, no existence; and it is certain, that the moving bodies apparent in the seminal fluid are not agitated by these spirits. But, that we may be enabled to pronounce more clearly concerning the nature of the semen, and of its animalcules, we shall present the reader with the principal observations which have been made on the subject.

Leeuwenhoek having examined the semen of a cock, perceived a number of animals similar to river eels; but they were so minute, that 50,000 of them were not equal in bulk to a grain of sand. Of those in the semen of a rat, it required, he says, many millions to make the thickness of a hair, &c. This excellent observer was persuaded, that the whole substance of the semen was only a mass of animalcules. He saw these animalcules in the semen of men, of quadrupeds, of birds, of fishes, and of insects. In the semen of a grasshopper, the animalcules were long, and extremely thin. They appeared, he says, to be attached by their superior end; and the other end, which he calls their tail, had a brisk motion, like that of the tail of a serpent

when its head is fixed. In the semen of young animals, when examined before they have any sexual appetite, he alleges that he saw the same minute animals, and that they had no motion: but, when the season of love arrived, the animalcules moved with great vivacity.

In the semen of a male frog, he saw animalcules; but, at first, they were imperfect, and had no motion: some time after he found them alive. They were so minute, he observes, that 10,000 of them were only equal in bulk to a single egg of the female.

In the semen of a man and that of a dog, he pretended to see two species of animalcules, resembling males and females. Having shut up the semen of the dog in a small phial, he says, that a great number of animalcules died the first day; that, on the second and third day, still more of them died; and that few of them were alive on the fourth day. But, having repeated this experiment on the semen of the same dog, he found, at the end of seven days, the animalcules as brisk and lively as if they had been newly extracted from the animal: and, having opened a bitch, that, some time before the experiment, had been three times covered by the same dog, he could not perceive, with his naked eye, any male semen in the uterus or its appendages; but, by the assistance of the microscope, he found the spermatic animals of the dog in both horns of the uterus: in that part of the uterus which is nearest the vagina, he discovered great numbers; which evidently proves, says he, that the

male semen enters the uterus, or, at least, that the spermatic animals of the dog had arrived there by their own motion, which enables them to pass over four or five inches in half an hour. In the uterus of a female rabbit, which had just received the male, he observed an infinite number of spermatic animals. He remarks, that the bodies of these animals are round; and that they have long tails; and that they often change their figure, especially when the fluid in which they swim begins to dry up.

These experiments of Leeuwenhoek were repeated by several people, who found them exactly consonant to truth. But Dalenpatius, and some others who were inclined to exceed Leeuwenhoek in acuteness of vision, alleged, that, in the semen of a man, they not only found animals resembling tadpoles, whose bodies appeared to be as large* as a grain of corn, with tails about four times as long as their trunks, and which moved with great agility; but, what is still more amazing, Dalenpatius saw one of these animals break through its coat or covering: it was then no more an animalcule, but a real human body, in which he easily distinguished the two arms and legs, the breast and the head*. But it is apparent, from the very figures given by this author of the embryo which he pretended to have seen escape from its covering, that the fact is absolutely false. He believed that

* See Nouvelles de la Republic des Lettres, ann. 1699, p. 552.

he saw what he describes; but he was deceived; for this embryo, according to his description, was more completely formed, at the time of its transmigration from the condition of a spermatic worm, than it is in the uterus of the mother at the end of the fourth or fifth week. Hence this observation of Dalenpatius, instead of being confirmed by future experiments, has been rejected by all naturalists, the most acute of whom have only been able to discover, in the seminal fluid of man, round or oblong bodies, which appear to have long tails, but no members of any kind.

One would be tempted to think that Plato had been acquainted with these spermatic animals, which are transformed into men; for, at the end of his Timæus*, he says, "Vulva quoque matrixque in fœminis eadem ratione animal avidum generandi, quando procul a fœtu per ætatis florem, aut ultra diutius detinetur, ægre fert moram ac plurimum indignatur, passimque per corpus oberrans, meatus spiritus intercludit, respirare non sinit, extremis vexat angustiis, morbis denique omnibus premit, quousque utrorumque cupido amorque, quasi ex arboribus fœtum fructumve producunt, ipsum deinde decerpunt, et in matricem velut agrum inspargunt: hinc animalia primum talia, et nec propter parvitatem videantur, necdum appareant formata, concipiunt; mox quæ conflaverant, explicant, ingentia intus enutriunt, demum educunt in lucem, animaliumque

* P. 1088, edit. Ficini.

generationem perficiunt." Hippocrates, in his treatise *De Diæta*, seems likewise to insinuate that the semen of animals is full of animalcules. Democritus talks of certain worms which assume the human figure; and Aristotle tells us, that the first men issued from the earth in the form of worms. But neither the authority of Plato, of Aristotle, of Hippocrates, of Democritus, nor that of Dalenpatius, will ever be able to bestow credibility on a notion which is repugnant to the repeated experience and observation of all those who have hitherto made inquiries into this subject.

Valisnieri and Bourguet perceived small worms in the semen of a rabbit: one of their extremities was longer than the other; they were very active in their motions, and beat the fluid with their tails: sometimes they raised themselves to the top of the liquor, and sometimes sunk to the bottom; at other times they turned round, and twisted like serpents: in fine, says Valisnieri, I clearly perceived them to be real animals: "E gli riconobbi, e gli giudicai senza dubitamento alcuno per veri, verissimi, arciverissimi vermi*. This author, though prejudiced in favour of the ovular system, admitted the actual existence of spermatic animals.

M. Andry pretends, that he could find no animals in human semen previous to the age of puberty; that they exist not in the semen of very old men; that there are few of them in those who

* See opere del Cav. Valisnieri, tom. ii. p. 105.

are affected with the venereal disease, and that these few are in a languishing state; that none of them appear alive in impotent persons; and that the animalcules in the semen of men have a larger head than those of other animals, which corresponds, he observes, with the figure of the fœtus and infant; and he adds, that those who use women too frequently have generally few or no animalcules in their semen.

Leeuwenhoek, Andry, and others, exerted every effort against the egg system: they discovered in the semen of all males living animalcules; they proved that these animalcules could not be regarded simply as inhabitants of this fluid, since the quantity of them was larger than that of the fluid itself; and since nothing similar to them existed either in the blood, or in any other of the animal fluids: they maintained, that as females furnished no animalcules, their fecundity was solely derived from the males; that the existence of living animals in the semen throws more light upon the nature of generation than all the former discoveries on this subject; because the greatest difficulty in generation is to conceive how life is first produced, the future expansion and growth of the parts being only accessory operations; and, consequently, that not a doubt remained of these animalcules being destined to become men, or perfect animals, according to their species. When the improbability was objected to them, that millions of animalcules, all equally capable of becoming men, should be em-

ployed for this purpose, while only one of them was to enjoy the singular advantage of being admitted into the condition of humanity; when it was demanded of them, why this useless profusion of human germs was employed? they replied, that it corresponded with the usual magnificence of Nature; that, in plants and trees, millions of seeds were produced, while only a few of them succeeded; and that, therefore, we ought not to be surprised at the prodigious number of spermatic animals. When the extreme minuteness of a spermatic worm, compared with the body of a man, was mentioned to them as a difficulty, they answered, that the seeds of trees, of the elm, for example, were equally minute, when compared with the perfect individuals; and they added, with equal propriety, metaphysical arguments, by which they proved, that largeness and minuteness were only relations, and that the transition from small to great, or from great to small, was performed by Nature with greater facility than we could possibly imagine.

Besides, they asked, are there not frequent examples of the transformation of insects? Do we not daily see small aquatic worms, by simply throwing off their skin or covering, from which they receive their external figure, transformed into winged animals? May not spermatic animalcules, by a similar transformation, become perfect animals? Every thing, therefore, they conclude, concurs in establishing this system of generation, and in overturning that which is

founded on the notion of eggs; and, though eggs really existed in viviparous animals, as well as in the oviparous, these eggs would only be the matter necessary for the growth and expansion of the spermatic worm, which enters by the pedicle which attaches the egg to the ovarium, where it finds abundance of nourishment. All the worms which are so unfortunate as to miss this passage through the pedicle into the egg, perish, and that one alone which finds the proper road is transformed into a perfect animal. The difficulty of finding this passage is sufficient to account for the great number and apparent profusion of the spermatic animals. It is a million to one against any individual worm's finding this passage; but, to compensate this difficulty, there are more than a million of worms. When a worm has once got possession of an egg, no other can enter into it; because, say they, the first worm shuts up the passage; or rather, there is a valve at the entry to the pedicle, which plays while the egg is not perfectly full; but, when the worm has filled the egg, this valve will not open, though pushed by a second worm. Besides, this valve is exceedingly well contrived; for, if the worm should chance to descend through the passage by which it entered, the valve prevents its escape, and obliges it to remain till it be transformed. The spermatic worm then becomes a real fœtus; and it is nourished by the substance of the egg, and the membranes serve it for a covering; and, when the nourishment contained in the egg begins to fail, the fœtus attaches itself to the inter-

nal surface of the uterus, and, by this means, extracts nourishment from the blood of the mother, till, by its weight, and the increase of its strength, it at last breaks off all connexion with the uterus, and issues into the world.

According to this system, it was not the first woman, but the first man, who contained all mankind in his own body. The preexistent germs are no longer inanimate embryos locked up in eggs, and included, *in infinitum*, within each other. They are, on the contrary, small animals, or organized living *homunculi*, included in each other in endless succession, and which, to render them men, or perfect animals, require nothing but expansion, and a transformation similar to that of winged insects.

As physicians are at present divided between the system of spermatic worms, and that of eggs, and as every new writer upon generation has adopted either the one or the other of these hypotheses, it is necessary to examine them with care, and to show not only their insufficiency to explain the phænomena of generation, but that they rest upon suppositions which are entirely destitute of probability.

Both systems suppose an infinite progression, which, as formerly remarked, is a mere illusion of the brain. A spermatic worm is more than a thousand million of times smaller than a man. If, then, the body of a man be taken as an unit, the body of a spermatic worm will be expressed by the fraction $\frac{1}{10000000000}$, *i. e.* by a number consisting of ten cyphers; and, as a man is to a

spermatic worm of the first generation in the same proportion as this worm is to a worm of the second generation, the size of this last spermatic worm will be expressed by a number consisting of nineteen cyphers; for the same reason, the size of a spermatic worm of the third generation must be expressed by a number consisting of twenty-eight cyphers, that of the fourth generation by thirty-seven cyphers, that of the fifth generation by forty-six cyphers, and that of the sixth generation by fifty-five cyphers. To form an idea of the minuteness represented by this fraction, let us take the dimensions of the sphere of the universe from the Sun to Saturn; and, supposing the Sun to be a million of times larger than the Earth, and distant from Saturn a thousand solar diameters, we shall find that forty-five cyphers are sufficient to express the number of cubic lines contained in this sphere; and, if we reduce each cubic line into a thousand million of atoms, no more than fifty-four cyphers will be necessary to express their number: of course, a man will be proportionally greater, when compared with a spermatic worm of the sixth generation, than the sphere of the universe when compared to the smallest atom that can be seen with the assistance of a microscope. But, if this calculation were carried on to the sixteenth generation, the minuteness would exceed all powers of expression. It is apparent, therefore, that the probability of this hypothesis vanishes in proportion as the object diminishes. This calculation*

applies equally to eggs as to spermatic worms; and the want of probability is common to both. It will, no doubt, be objected, that, as matter is infinitely divisible, this gradual diminution of size is not impossible. To this I reply, that all infinities, whether in geometry or in arithmetic, are only mental abstractions, and have no actual existence in Nature. If the infinite divisibility of matter is to be regarded as an absolute infinite, it is easy to demonstrate, that, in this sense, it has no existence; for, if we once suppose the smallest possible atom, by the very supposition, this atom must be indivisible; because, if it were divisible, it would not be the smallest possible atom, which is contrary to the supposition. It is, therefore, apparent, that every hypothesis which admits an infinite progression ought to be rejected not only as false, but as destitute of every vestige of probability; and, as both the vermicular and ovular systems suppose such a progression, they should be excluded for ever from philosophy.

These systems are liable to another objection: in the ovular system, the first woman contained both male and female eggs; the male eggs could only give origin to males; but the female eggs must have contained millions of generations of both males and females: hence every woman must have always contained a certain number of eggs capable of being unfolded *in infinitum*, and another number, which could only be unfolded once, and could have no farther ope-

ration in the series of existence. The same thing must take place in the vermicular system. Hence we may conclude, that there is not the smallest degree of probability in hypotheses of this nature.

A third difficulty still remains, arising from the resemblance of children sometimes to the father, sometimes to the mother, and sometimes to both, and from the evident characters of specific differences in mules and other monstrous productions. If the fœtus proceeds from the spermatic worm of the father, how comes the child to resemble its mother? If the fœtus pre-exists in the egg of the mother, how should the child resemble its father? And if the spermatic worm of a horse, or the egg of a she ass, be the origin of the fœtus, how should the mule partake of the nature and figure both of the horse and ass?

These general objections, though perfectly invincible, are not the only difficulties with which both systems are embarrassed. May it not be demanded of those who embrace the vermicular system, how these worms are transformed, and wherein consists the analogy between this transformation and that which insects undergo? The caterpillar, which is to become a butterfly, passes through a middle state, and, after it ceases to be a chrysalis, is completely formed, has acquired its full growth, and is instantly capable of generating: but, in the pretended transformation of the spermatic worm of a man, there is no middle or chrysalis state; and, sup-

posing it should happen during the first days of conception, why is not the production of this chrysalis, in place of an unformed embryo, a perfect adult? Here all analogy ceases; and, of course, the notion of the transformation of the spermatic worm can receive no support from this quarter.

Besides, the worm which is to be transformed into a fly proceeds from an egg; this egg is impregnated by the copulation of the male and female, and it includes the fœtus, which is to pass into a chrysalis, before it arrives at the perfect state of a fly, and before it acquires the power of generating. But the spermatic worm has no generative faculty; neither does it proceed from an egg: and, though it should be supposed that the semen contains eggs which produce the spermatic animals, the same difficulty still remains; for these supposed eggs are not a result of the copulation of two sexes, like those of insects. Consequently the analogy fails here likewise; and the transformation of insects, in place of strengthening this hypothesis, seems to destroy it entirely.

The seeds of vegetables are resorted to, in order to account for the infinite number of spermatic animals: but this analogy does not apply; for all the spermatic animals, one only excepted, must absolutely perish. The seeds of vegetables, however, are not subject to the same necessity. When they become not vegetables themselves, they nourish other organized bodies, and serve the purposes of growth and of repro-

duction to animals. But the prodigious superfluity of spermatic animals can answer no end whatever. I make this remark, purely because I wish to omit nothing that has been advanced on the subject; for I acknowledge, that no argument drawn from final causes can either establish or destroy a physical theory.

The apparent equality in the number of spermatic animalcules in all animals, has also been objected to by the supporters of this doctrine. If these animalcules are the immediate cause of generation, why is there no proportion between their numbers and those of the young, which are various in men, quadrupeds, birds, fishes, and insects? Besides, there is no proportional difference in most species of spermatic animals, those of a rat being nearly equal in size to those of a man. Even when a difference in size takes place, it has no proportion to the bulk of the animals. The spermatic animals of the calmar, which is a small fish, are 100,000 times larger than those of a man or of a dog. This is an additional proof that these worms are not the sole and immediate cause of generation.

The particular objections to the ovular system are not less weighty. If the fœtus existed in the egg before the junction of the male and female, why do we not see the fœtus in the egg before impregnation, as clearly as after it? We formerly mentioned that Malpighius always found the fœtus in eggs which had received the impregnation of the male, and could discover nothing but an unformed mole or mass in the

cicatrice of unimpregnated eggs. It is, therefore, evident, that the fœtus is never formed till the egg has been impregnated.

Farther, we not only cannot discover the fœtus in eggs before the intercourse of the sexes, but we have not been able to demonstrate the existence of eggs in viviparous animals. Those physicians who pretend that the spermatic worm is the fœtus inclosed in a coat or covering, are at least ascertained of the existence of spermatic worms; but those who maintain that the fœtus preexists in the egg, have no evidence of the existence of the egg itself; for the probability of the nonexistence of eggs in viviparous animals amounts almost to a certainty.

Though the partizans of the ovular system agree not as to what ought to be regarded as the real egg in the testicles of females, they all allow, however, that impregnation is accomplished in the testicles or ovarium. But they never consider, that, if this were the case, most fœtuses would be found in the abdomen instead of the uterus; for, as the superior extremity of the Fallopian tube is unconnected with the ovarium, the pretended eggs would often fall into the abdomen. Now, we know this to be at least a very rare phænomenon; and it is probable that it never happens but by means of some violent accident.

These objections and difficulties have not escaped the ingenious author of *Venus Physique.* But, as his work is in the hands of the public, and as it admits not of abridgment, we shall

refer the reader to the book itself; and shall conclude with an account of a few particular experiments, some of which appeared to favour, and others to contradict the above systems.

In the History of the Academy of Sciences, ann. 1701, some objections are proposed by M. Mery against the egg system. This able anatomist maintained, with propriety, that the vesicles found in the testicles of females are not eggs; that they adhere so firmly to the internal surface of the testicle, as not to admit of a natural separation; and that, though they could separate from the substance of the testicle, it was impossible for them to get out of it, because the texture of the common membrane inclosing the whole testicle is so firm and strong, that it is impracticable to conceive the possibility of its being pierced by a vesicle, or round soft egg. And, as most anatomists and physicians were prepossessed in favour of the egg system, and imagined that the number of cicatrices in the testicles corresponded with the number of fœtuses, M. Mery showed such a quantity of these cicatrices in the testicles of a woman, as, upon the supposition of the truth of this system, would have argued a fecundity beyond the power of credibility. These difficulties stimulated other anatomists of the Academy, who were partizans of the eggs, to make new researches. M. Duverney examined the testicles of cows and sheep, and maintained that the vesicles were eggs, because some of them adhered less firmly to the testicles than others; and that it was natural to suppose

they separated altogether when they arrived at full maturity; especially as, by blowing into the cavity of the testicle, the air passed between the vesicles and the adjacent parts. M. Mery simply replied, that this proof was insufficient, as these vesicles were never seen separate from the testicles. M. Duverney farther observed the glandulous bodies upon the testicles; but he never considered them as parts essential to generation, but as accidental excrescences, like gall-nuts on the oak. M. Littre, whose prejudices in favour of eggs were still stronger, maintained not only that the vesicles were eggs, but even assured us, that he discovered in one of them a well formed fœtus, of which he could distinguish both the head and trunk; and he has even given their dimensions. But, admitting this wonder, which never appeared to any eyes except his own, to be convinced of the doubtfulness of the fact, we have only to peruse his memoir*. From his own description, it appears that the uterus was schirrous, and the testicle very much corrupted; that the vesicle or egg, which contained the pretended fœtus, was much less than common, &c.

Nuck furnishes us with a celebrated experiment in favour of eggs. He opened a bitch three days after copulation; he drew out one of the horns of the uterus, and tied it in the middle, so as to prevent the superior part of the Fallopian tube from having any communication with the

* Ann. 1701, p. 111.

inferior. After this, he replaced the horn of the uterus, and closed the wound. Twenty-four hours afterwards, he again opened the wound, and found two fœtuses in the superior part of the tube, that is, between the testicles and the ligature; and there was no fœtus in the under part. In the other horn of the uterus that was not tied, he found three fœtuses, regularly disposed; which proves, says he, that the fœtus proceeds not from the male semen, but that it exists in the egg of the female. Supposing this experiment, which is single, had been often repeated with the same success, the conclusion the author draws from it is not legitimate; it proves no more than that the fœtus may be formed in the superior part of the horn of the uterus, as well as in the inferior; and it is natural to think, that, by the pressure of the ligature, the seminal liquor in the inferior part was forced outward, and, of course, frustrated the work of generation in that region of the uterus.

This is all the length that anatomists and physicians have proceeded in the subject of generation. It only remains that I deliver the results of my own experiments and inquiries; and I shall leave the reader to judge whether my system be not infinitely more consonant to Nature than any of those which I have enumerated.

CHAP. VI.

Experiments on Generation.

I OFTEN reflected on the above two systems of generation, and was daily more and more convinced that my theory was infinitely more probable. At length I began to suspect that those *living organic particles, from which I thought animals and vegetables derived their origin,* might be recognised by the assistance of good glasses. My first notion was, that the spermatic animalcules found in the seminal fluid of all males, might probably be those very organic particles; and I reasoned in this manner. If all animals and vegetables contain an infinite number of living organic particles, these particles should be found in their seeds, because the seed is an extract from all the organic parts, and especially from those which are most analogous to the individual: perhaps the spermatic animals found in the semen of males may actually be those very organic particles, or, at least, the first union or assemblages of them. But, if this be the case, then the semen of females ought to contain organic living particles, or animalcules, similar to those of the male. They ought, for the same reason, to be found in the seeds of plants, in the

nectarium, and in the stamina, which are the most essential parts of vegetables, and contain the organic particles necessary for their reproduction. I therefore determined to examine with the microscope the seminal liquors of males and females, and the germs of plants; and, at the same time, I imagined that the cavities of the glandulous bodies of the uterus might be the reservoirs of the female semen. Having communicated my ideas of this subject to my ingenious friends Mr. Needham, M. Daubenton, M. Gueneau, and M. Dalibard, they encouraged me to commence a set of experiments, in order to throw light upon *this mysterious operation of Nature.*

...ese gentlemen occasionally attended and ... e: but particularly M. Daubenton, who ... absent, and who was witness to every ... I made.

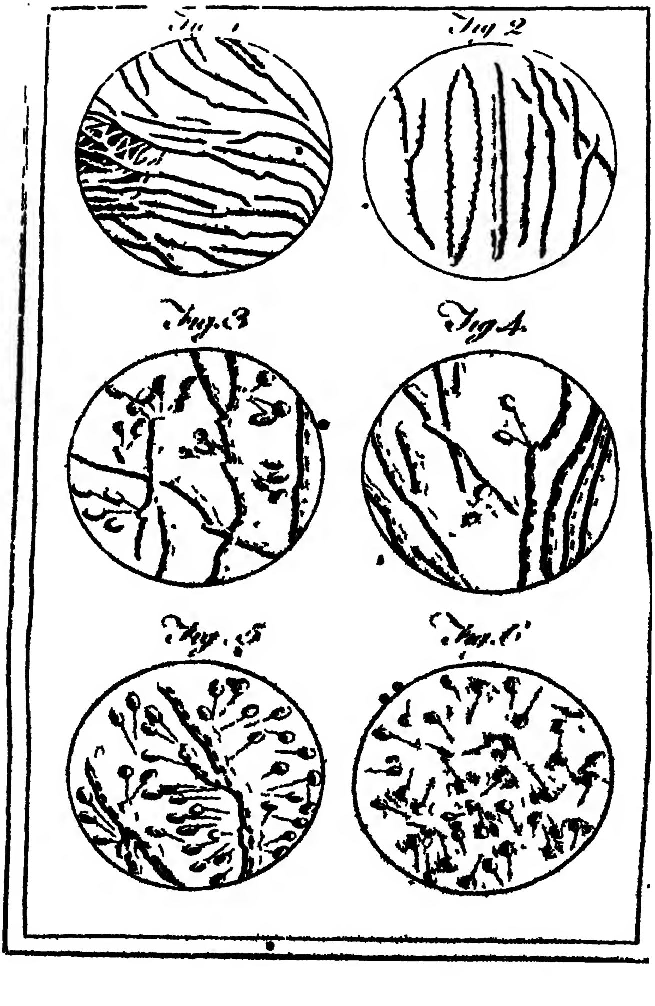
...d a double microscope, which I had ...eedham, being the same with which ... numerous and ingenious ...serva- ... instrument is infinit... ...rable ...ved by Leeuw...

1745.
... mentions th... ...e some precauti... ... the which, now that th... ... is well known, and much improved since the au... ...te, it is unnecessary to translate.

EXPERIMENT I.

Having procured the seminal vessels of a man who died a violent death, and whose body was still warm, I extracted all the liquor from them, and put it in a phial. I examined, by the microscope, a drop of this liquor, without any dilution. As soon as the vapours, which arose from the liquor and obscured the glass, were dissipated, I observed pretty large filaments (plate ix. fig. 1), which, in some places, spread out into branches, and, in others, intermingled with each other. These filaments clearly appear to be agitated with an internal undulatory motion, like hollow tubes, which contained some moving substance. I saw distinctly (pl. ix. fig. 2) two of these filaments [illegible] which were joined longitudinally, separat[illegible] other in the middle, and alter[illegible] and recede, like two stretched [illegible] ends, and drawn asunder at [illegible] ments were composed of [illegible] one another, and resem[illegible] beads. I then observed filamen[illegible] 3) which were blown up, and swelled [illegible] places, and perceived small oval gl[illegible] from these swelled parts, which had a vibratory motion, like that of a pendulum [illegible] 4). These small bodies were attached to the filaments by little threads, which gradually lengthened as the bodies [illegible]; and, lastly, I observed these small bodies detach

Plate 9



themselves entirely from the large filament, and draw after them the little thread, which resembled a tail. As the liquor was too thick, and the filaments too near each other, I diluted another drop with pure rain water, after satisfying myself that it contained no animalcules. I then perceived that the filaments were more distant from each other, and saw distinctly the motion of the small bodies above taken notice of (pl. ix. fig. 5), which was more free, and they appeared to swim with greater agility, and trailed their threads after them with greater ease; and, if I had not seen them separate from the filaments, and draw the threads out of them, I should have believed, from this second observation, the moving bodies to be real animals, and their threads to be tails. After examining with great attention one of the filaments, which was three times thicker than the small bodies, I perceived two of these bodies detach themselves, with much difficulty, and drag after them long slender threads, which impeded their motion.

This seminal liquor was at first too thick: but it gradually became more fluid, and in less than an hour it was almost transparent; and, in proportion as its fluidity augmented, the phænomena changed, in the manner to be just mentioned.

EXPER. II.

When the seminal liquor became more fluid, the filaments disappeared; but the small bodies were exceedingly numerous (pl. ix. fig. 6). Their motion, for the most part, resembled that of a pendulum; each of them had a long thread, from which they evidently endeavoured to disengage themselves; their progressive motion was extremely slow, during which they vibrated to the right and left. At each vibration, they had a rolling, unsteady motion; so that, besides their horizontal vibrations, they roll or vibrate in a verticle direction; which proves these bodies to be of a globular figure, or at least that their inferior part is not a flat base sufficiently extensive to keep them in one position.

EXPER. III.

At the end of two or three hours, when the liquor was more fluid, a still greater number of these moving bodies appeared (pl. x. fig. 7). They were more free of incumbrances; their threads were shorter; their progressive motion was more direct; and their horizontal vibration was greatly diminished; for the longer the threads were, their vibratory motion was increased, and their progress forward was diminished. The vertical vibration was still apparent.

EXPER. IV.

In five or six hours, the liquor had almost all the fluidity it could acquire, without being decomposed. We then discovered (pl. x. fig. 8) that most of these small moving bodies were entirely disengaged from their threads. Their figure was oval; they moved forward with considerable quickness; and, by their motion backward and forward, and to every side, they had now more than ever the appearance of real animals. Those which had tails or threads sticking to them, seemed to have less vivacity than the others. Of those which had no threads, some appeared to change both their figure and their size. Some were round; but the greatest part of them were oval, and a few were thicker at the extremities than in the middle. The rolling and vibratory motions were still perceptible.

EXPER. V.

In twelve hours, the liquor had deposited, at the bottom of the phial, a kind of gelatinous, bluish, or rather ash-coloured substance; and the fluid that swimmed on the top was nearly as clear as water, only it had a tincture of blue, like water in which a small quantity of soap has been dissolved. It still, however, retained its viscosity. The little bodies, which were now entirely freed

from their threads, moved with great activity on all sides, and some of them turned round their centres. Most of them were oval, though some of them were round. I have seen them change figures, and from oval become round: I have seen them divide, and, from a single oval or globule, separate into two. Their activity always increased as their size diminished.

EXPER. VI.

At the end of twenty-four hours, the liquor had deposited a greater quantity of gelatinous matter, which I diluted, with some difficulty, in water. It appeared to consist of a multitude of opaque tubes, resembling lace, but without any regularity or the smallest motion. In the clear semen itself, there were a few small bodies still moving; next day their number was still farther diminished. After this nothing was to be seen but globules without the least appearance of motion.

These experiments were often repeated with great exactness; and they convinced me that the threads which adhere to the moving bodies are not tails, nor any part proper to these bodies; for the tails or threads have no proportion to the rest of the body; they are of different dimensions, though the bodies are always nearly of the same size at the same time. The motion of the globule is embarrassed in proportion to the length of the tail. When the tail is too long,

it sometimes prevents the progressive motion altogether, leaving nothing but the vibrations from right to left; and the globules make evident efforts to disentangle themselves from this incumbrance.

EXPER. VII.

Having procured the seminal fluid of another man recently dead, I put a pretty large drop of it on the glass, which soon liquified without any mixture. It had the appearance of a close network, the filaments of which were of a considerable length and thickness, and they seemed to proceed from the thickest part of the liquor (pl. x. fig. 9). These filaments separated in proportion as the liquor became more fluid; and at last they divided into globules, which seemed at first to have too little force to put them in motion: but their power of moving increased as they receded from the filaments, and they appeared to make considerable efforts to disengage themselves. In this manner each of them gradually drew tails of different lengths out of the filaments. Some of these tails were so long and so thin, that they had no proportion to the bodies, which were always more or less embarrassed, according to the length of the threads or tails. When the tail was long, the angle of the vibratory motion was increased; and, when the tail was short, the progressive motion was more conspicuous.

EXPER. VIII.

I continued my observations, almost without interruption, for fourteen hours, and I discovered, that the length of the tails or threads gradually diminished, and became so thin and delicate, that their extremities successively ceased to be visible; and at last the whole disappeared. The horizontal vibrations of the globules then ceased, and their progressive motion was direct, though they still had verticle oscillations, or, rather, they rolled like a vessel at sea. The small bodies, when deprived of their tails, were oval and transparent, and resembled those pretended animals which are seen in oyster water on the sixth or seventh day, or those found in the jelly of roasted veal at the end of the fourth day.

EXPER. IX.

Between the tenth and twelfth hour, the liquor was become very fluid, and all the globules appeared to proceed in troops from one side of the drop (pl. x. fig. 10). They passed over the field of the microscope in less than four seconds; they marched in lines of seven or eight in front; and succeeded each other without interruption, like the defiling of soldiers. I observed this singular phænomenon for more than five minutes; and, as the current of animals did not then cease,

I was desirous of discovering the cause. I therefore gently shifted the glass, and perceived that all these moving globules proceeded from a kind of mucilage (pl. x. fig. 11), or net-work of filaments, which continually produced them, and with more rapidity and copiousness than the filaments had done ten hours before. There was still a difference more remarkable between the globules produced by the liquor, when thick, and those produced when it was more fluid; for, in the latter case, they drew no threads or tails after them, their motion was quicker, and they went in flocks like sheep. I examined the mucilage from which they proceeded for a long time, and perceived that it gradually diminished and was converted into moving globules, till more than one half of it was destroyed. After which, the liquor being too dry, this mucilage became obscure in the middle, and it was surrounded with small threads, forming square intervals (pl. x. fig. 12). These small threads seemed to be composed of the bodies of the moving globules which had been killed by the drying of the liquor, and the whole resembled the web of a spider besprinkled with drops of dew.

EXPER. X.

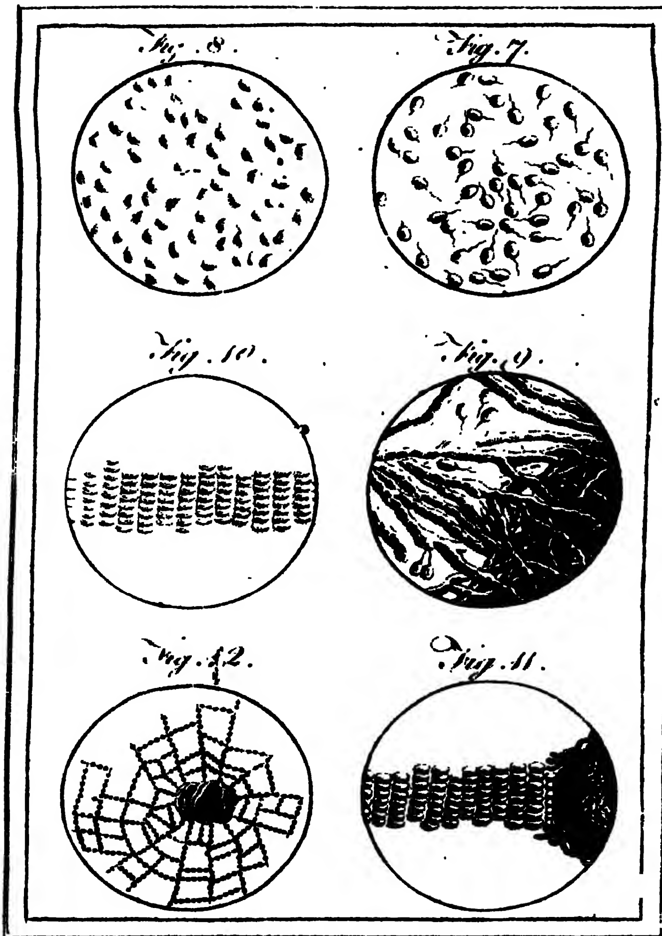
By the first experiments, I perceived that these small moving bodies changed their figures; and I imagined, that, in general, they diminished in bulk, though I was not then altogether certain

of the fact. But my subsequent observations removed every doubt. At the twelfth and thirteenth hour, the bodies were visibly smaller; but, as they diminished in bulk, their specific gravity increased, especially when they ceased to move, which they generally did all at once, and fell down to the bottom in the form of an ash-coloured sediment, which was perceptible by the naked eye; and, by the assistance of the microscope, it appeared to be composed of globules attached to one another, sometimes by threads, and at other times in groups, but always in a regular manner.

EXPER. XI.

Having procured the fresh semen of a dog, I observed that this liquor was clear, and had very little tenacity. I examined it without the addition of water, and I perceived moving bodies almost entirely similar to those in the human semen (pl. xi. fig. 13). Their tails and their form were almost precisely the same with those represented in pl. x. fig. 7, where the liquor had been liquified for two or three hours. I in vain searched this liquor for the filaments which appeared in that of men. I only remarked some long and very delicate threads, exactly similar to those which served for tails to the globules. These threads contained no globules; neither had they any motion. The globules with tails seemed to move with more vivacity than those in the hu-

Plate 10



man semen. They had hardly any horizontal vibrations; but they always rolled vertically. Their number was not great; and, though their progressive motion was quicker, they took up some time in passing over the field of the microscope. I examined this liquor during three hours, and could observe no change. I continued my examination, from time to time, for several days, and remarked, that the number of moving bodies gradually diminished. On the second day, the greatest part of them had lost their tails: on the third, very few of them retained their tails; on the fourth, however, some tails still adhered. The liquor had now deposited a whitish sediment, which appeared to be composed of globules without motion, and some small threads that seemed to be the tails which had separated from the globules. Some globules appeared to have dead ones attached to them; for their figure differed from that of those in motion (pl. xi. fig. 14): they were larger than the moving globules, or the dead ones at the bottom of the liquor, and seemed to have a kind of fissure or opening.

EXPER. XII.

At another time I examined the seminal fluid of the same dog, and perceived the same phænomena which have been described. I farther observed, in a drop of this liquor, a mucilaginous part (pl. xi. fig. 15), from which globules issued

as in exper. ix. and these globules formed a current, and moved in regular troops. This mucilage appeared to be agitated internally with a swelling or undulating motion, which produced small protuberances in different parts; and these protuberances issued suddenly in the form of globules, which moved briskly forward in the same direction. These globules differed not from the others, except that they issued from the mucilage without tails. Some of them, I remarked, changed their figure; they lengthened themselves till they resembled small cylinders; after which the extremities of the cylinders swelled, and divided by the middle into two globules, and both of them moved on in the same direction with the rest.

EXPER. XIII.

The small glass which contained this liquor having been overturned by accident, I took, from the same dog, another quantity of semen. But, whether the animal had been fatigued by too frequent emissions, or from some other cause, this seminal liquor contained nothing: it was transparent and viscous, like the serum of blood; and, though I examined it, at different times, for twenty-four hours, I could perceive no moving bodies, no mucilage, nor, in a word, any thing similar to what I had formerly seen.

EXPER. XIV.

I then opened a dog, and took out the testicles, and the vessels adhering to them; but I remarked, that he had no seminal vessels: the semen of this animal probably passes directly from the testicles into the urethra. Though the dog was full grown and vigorous, I found very little semen in the testicles. I examined with the microscope the small quantity I could collect; but could perceive no moving bodies: I saw only a great number of very minute globules, the greatest part of which were motionless; and some of the smallest of them seemed to move towards each other. But of this I could not be certain; because the small drops dried in a minute or two after they were put upon the glass.

EXPER. XV.

I cut the testicles of this dog into two parts, put them into a glass vessel, with as much water as was sufficient to cover them, and corked up the glass. Three days after, I examined this infusion with a view to discover if the flesh contained any moving bodies, and I perceived in the water of this infusion a great number of moving bodies, some of them of a globular, others of an oval figure, and entirely resembling

those I had seen in the seminal fluid of the former dog, except that they had no threads or tails: they moved in all directions with great vivacity. I observed, during a long time, these bodies, which appeared to be animated, and I perceived several of them change their figures before my eyes. Some of them lengthened, others contracted, and others swelled at the two extremities. The whole of them seemed to turn on their centres; some of them were larger, and others smaller; but the whole were in motion, and resembled, both in size and figure, those which were described in exper. iv.

EXPER. XVI.

Next day, the number of moving globules was still increased; but they were smaller; their motion more rapid and more irregular; and their form and manner of moving were different, and appeared to be more confused: the day after, and the following days, till the twentieth, moving bodies still appeared in this water. They daily diminished in size, and at last became so small that they could hardly be perceived; but the last of them I was able to distinguish on the eighteenth and twentieth days, moved with the same rapidity as ever. On the top of the water there was a pellicle which appeared to be composed of the skins or coverings of the moving bodies, of small threads, &c. But no motion appeared in it. This pellicle and the mov-

ing bodies could not be introduced into the liquor by means of the external air; for the bottle was always closely corked.

EXPER. XVII.

I opened successively, on different days, ten rabbits, in order to examine their seminal fluid. In the first, second, and third, I found not a single drop, either in the testicles or seminal vessels, though I was certain that two of them were fathers of a numerous progeny. I imagined that the presence of the female might be necessary for the secretion of the semen; I therefore put males and females by pairs into separate cages, so constructed that they could not possibly copulate. Neither did this scheme at first succeed; for I opened two of them without finding any semen. In the sixth, however, which was a large white rabbit, full of vigour, I found as much liquor in the seminal vessels as would fill a small coffee-spoon. This matter resembled the jelly of meat, was of a citron colour, and almost transparent. Having examined it with the microscope, it gradually separated into filaments and large globules, several of which were attached to each other, like a string of beads; but I could discover no distinct motion; only, as the matter dissolved, it formed a kind of current, by which the filaments and globules were carried down to one side of the glass. I waited till the matter should become more fluid; but I was dis-

appointed; for, after liquifying a little, it dried up, and I could observe nothing farther than what I have already described. I then added water to it, but without success; for the water seemed not to penetrate or dilute the matter.

EXPER. XVIII.

I opened another rabbit, and found only a small quantity of seminal matter, which had hardly any of the yellow colour, and was more fluid than the former. As the quantity was very small, I was apprehensive lest it should dry too suddenly; I therefore instantly mixed it with water, and could perceive in it neither the filaments nor the strings of beads that I had observed in the other; but I discovered the large globules, and farther remarked, that they had a kind of trembling, restless motion. They had also a progressive motion; but it was very slow: some of them moved round others, and most of them appeared to turn round their centres. I could proceed no farther in my observations, because the liquor dried suddenly up.

EXPER. XIX.

Having dissected another rabbit that had been placed in the same circumstances, I found no seminal liquor; but, in the seminal vessels of another, I found nearly as much congealed mat-

ter as in exper. xvii. I examined this matter without discovering any thing. I therefore took the whole, and, adding to it a double quantity of water, shook the mixture violently in a glass. I then left it to settle for ten minutes; after which I examined a drop taken from the surface, and perceived the large globules formerly mentioned, but they were few in number, and perfectly detached from one another. They moved towards each other; but this motion was so slow, as to be hardly perceptible. Two or three hours after, the globules seemed to be diminished in size; their motion was more sensible: and they turned upon their centres. Though their trembling was more apparent than their progressive motion; yet they plainly changed places in an irregular manner with respect to each other. In six or seven hours, the globules were become smaller, and their activity was greater. Their number appeared to be great, and all their motions were sensible. Next day there was a prodigious multitude of moving globules, and they were at least three times smaller than at first. I continued my observations for eight days, and I perceived that several of the globules joined; and, though all motion ceased after this union, it appeared to be superficial and accidental only. Some of them were larger, and others less; though most of them were spherical, some were oval, and others cylindrical. The largest were most transparent; and the smallest were almost black. This difference could proceed from no accident in the light; for they were always of

the same colour, whatever was their situation; The motion of the small globules was likewise more rapid. The whole gradually diminished in size; so that on the eighth day, they were so small, that it was with the utmost difficulty I could distinguish them, and at last they totally disappeared.

EXPER. XX.

In fine, having, with great difficulty, procured the seminal liquor of another rabbit, in the very state in which it is conveyed into the female, I remarked, that it was much more fluid than that which was extracted from the seminal vessels; and the phænomena it presented were also very different: for, in this liquor, there were moving globules, filaments without motion, and a kind of globules with tails or threads, similar to those in the seminal fluid of man and of the dog, only these last appeared to be less, and more active (pl. xi. fig. 17). They traversed, in an instant, the field of the microscope: their tails seemed to be much shorter than those of other spermatic animals; and I acknowledge, that I was uncertain whether some of these tails were not deceptions occasioned by the track of the globules in the liquor; for they moved with such rapidity, that I could hardly observe them; and, besides, the liquor, though sufficiently fluid, dried very suddenly.

EXPER. XXI.

Having procured, at different times, the testicles and seminal vessels of twelve or thirteen rams, recently after they were killed, I could not find, either in the epidydimis or seminal vessels, a quantity of semen sufficient for observation. In the small drops I could collect, I found nothing but globules without motion. As these experiments were made in March, I imagined that, by repeating them in October, which is the time of rutting, I might find more liquor in the vessels. I cut several testicles in two longitudinally, and, having collected a small drop of liquor, I still could perceive nothing but motionless globules of different sizes.

EXPER. XXII.

I took three testicles of three different rams, cut them into four parts, and put each of them into a glass vessel, with as much water as was sufficient to cover them, and then shut the vessels so close as to exclude the air. I allowed the testicles to infuse during four days; after which I examined the liquor in each glass with the microscope, and found the whole full of moving bodies; most of which were oval, and some of them globular. They were equally large, and

greatly resembled those described in exper. viii. Their motion was not rapid, but equal, uniform, and in all directions. In each liquor, the moving bodies were nearly of the same size; but, in the one they were larger, in the other less, and, in the third, still more minute: they had no tails; neither were there, in the liquor, any threads or filaments. They often changed their figures, and seemed successively to cast their skin or outer covering. They daily became smaller, and, on the sixteenth day, they were so small as scarcely to be visible.

EXPER. XXIII.

In the following October, I opened a ram, and found a great quantity of seminal liquor in the epidydimis. Having examined it with the microscope, I saw such an innumerable multitude of moving bodies, that the liquor seemed to be entirely composed of them. As the liquor was too thick, I diluted it with water; but I was astonished to find, that the water had stopped all motion in the bodies; though I saw them distinctly in the liquor, they were all at absolute rest. Having frequently repeated the same experiment, I discovered, that cold water, which diluted the seminal liquors of other animals, made that of the ram coagulate.

EXPER. XXIV.

I then opened another ram, and, to prevent the liquor from coagulating by cold, I left the parts of generation in the body of the animal, which was covered with warm cloths. This precaution afforded me an opportunity of examining with ease the seminal liquor of many rams in its fluid state. It was filled with an infinite number of oblong moving bodies (pl. xi. fig. 18), which ran about in every direction. But, whenever the liquor cooled, all motion instantly ceased; so that I never could observe the same drop above a minute or two. When I diluted the liquor with warm water, the bodies continued to move for three or four minutes. The moving bodies were so numerous, that, though the liquor was diluted, almost all of them touched each other. They were all of the same size and figure. None of them had tails. Their motion was not rapid; and, when the liquor began to coagulate, they suffered no change in their form.

EXPER. XXV.

As I was persuaded, both by my theory and the experiments made by others upon this subject, that the female, as well as the male, possessed a prolific seminal fluid; and, as I had no

doubt but that the glandulous bodies of the testicles, where prejudiced anatomists had in vain searched for the egg, were the reservoirs of this fluid; I purchased several dogs and bitches, and male and female rabbits, which were kept separate from each other: and, that I might have an object to compare with the female fluid, I again examined the seminal liquor of a dog, which had been emitted in a natural manner. I found the moving bodies in the same state, and attended with the same circumstances as formerly (pl. xii. fig. 19).

EXPER. XXVI.

A live bitch was next dissected, which had been four or five days in season, without having any communication with the male. The testicles were as large as filberds. On one of them I found a red, prominent, glandulous body, of the size of a pea, which had a perfect resemblance to a little nipple, with a visible fissure, that had two lips, one of which was more prominent than the other. Having opened this fissure, a liquor distilled from it, which we collected for examination. The testicles were then returned into the body of the animal, which was still alive, in order to preserve them from cooling. I then examined this liquor with the microscope, and had the satisfaction of perceiving, at the first glance, moving bodies with tails, exactly similar to those which we had observed in the seminal

Plate II

Fig. 13.

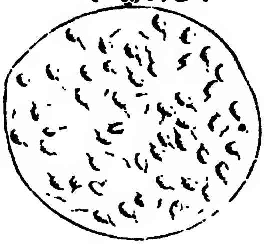


Fig. 14.

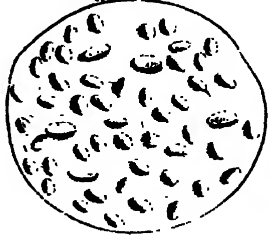


Fig. 15.

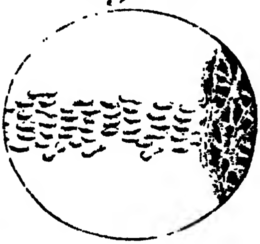


Fig. 16.

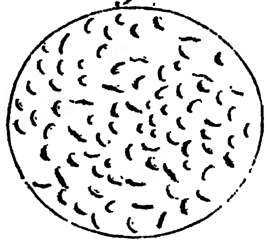


Fig. 17.

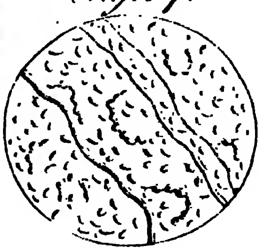
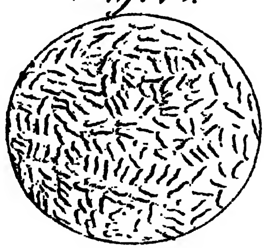


Fig. 18.



fluid of the dog (pl. xii. fig. 20). Messrs. Needham and Daubenton, who were present, were so struck with this resemblance, that they could not be persuaded that the spermatic animals were not the very same; and they imagined that I had forgotten to change the object glass, or rather, that the same pick-tooth with which the drops of the female fluid were collected, had also been employed in collecting those of the male. Mr. Needham, therefore, changed both the object glass and the pick-tooth, and took a fresh drop from the fissure of the glandulous body, and examined it first with his own eyes. He again saw the very same moving bodies, and was fully convinced, not only of the existence of spermatic animals in the seminal fluid of the female, but also of their resemblance to those in the semen of the male. We repeated the experiment with fresh drops no less than ten times, in all of which the phænomena were exactly the same.

EXPER. XXVII.

Having then examined the other testicle, I found an unripe glandulous body, which was smaller, and less red than the former, and had no fissure; but, after opening it with a scalpel, I found no liquor. Upon the external surface of this testicle, there were some lymphatic vesicles. I pierced one of them with a lancet, and there issued a clear liquor, to which I immediately

applied the microscope. But it contained nothing similar to what we discovered in that of the glandulous body. It was a transparent liquor, composed of very small globules, without any motion. After repeating this experiment several times, I was convinced, that the liquor in the vesicle is only a species of lymph, which contains nothing animated or similar to what we perceive in the female semen, which is secreted and matured in the glandulous bodies.

EXPER. XXVIII.

Some time after, another bitch was opened, which had been seven or eight days in season, and had not received the male. I examined the testicles, and upon each I found a glandulous body in full perfection. The first was half open, and had a canal which penetrated the testicle, and was full of seminal fluid; the second was larger and more prominent, and the fissure or canal that contained the fluid was below the nipple, which protruded outward. I took the liquor out of both the glandulous bodies, and, on comparison, found them entirely similar. This seminal liquor of the female is equally fluid with that of the male. After examining the liquors extracted from each testicle, I found in them the very same moving bodies (pl. xii. fig. 21). I perceived at leisure the same phænomena that I had observed in the seminal liquor of the other

bitch; I saw several globules, which moved with great rapidity, which endeavoured to disengage themselves from the mucilage that surrounded them, and which dragged tails or threads after them. Their number was equally great with that in the male semen.

EXPER. XXIX.

I squeezed the whole liquor out of these two glandulous bodies, and put it into the glass of a watch. The quantity was sufficient to serve for four or five hours' observation. I remarked that it deposited a kind of sediment, or at least began to thicken. I took a drop of the thickest part of the liquor, and, having examined it, I discovered that the mucilaginous part of the semen was condensed, and formed a kind of net-work. From the anterior edge of this net-work, there issued a current of globules which moved with great rapidity (pl. xii. fig. 22). These globules were extremely active and lively, and they appeared to be divested of their mucilaginous coverings and of their tails. This stream of globules resembled the motion of the blood in the veins; for they seemed not only to be animated, but to be pushed on by some common force, which obliged them to follow each other in troops or rows. From this experiment, and from the eleventh and twelfth, I concluded, that, when the fluid begins to coagulate or grow thick, the active globules break their mucilaginous covering,

and escape at that side where the liquor is most fluid. They had no threads or tails, and most of them were oval, and seemed to be flat below; for they had no rolling motion.

EXPER. XXX.

I opened the horns of the uterus longitudinally, and, having squeezed a little liquor out of them, I found it exhibited precisely the same phænomena with that obtained from the glandulous bodies. These glandulous bodies are so situated, that they can easily pour their liquor upon the horns of the uterus: and I am persuaded that, during the whole season of love, there is a perpetual distillation of this liquor from the glandulous bodies into the horns of the uterus; that this distillation continues till the glandulous bodies be entirely emptied; and that they are gradually effaced, leaving behind them only a small reddish cicatrice on the external surface of the testicle.

EXPER. XXXI.

I mixed the seminal liquor of the female with an equal portion of that of the male, which was recently emitted; but the moving bodies, and every circumstance, were so entirely the same, that I could make no distinction between those of the male and those of the female.

EXPER. XXXII.

Having dissected a young bitch that had never been in season, I discovered, on one of the testicles only, a small solid protuberance, which I imagined to be the rudiments of a glandulous body. The surface of the testicles was smooth and uniform, and it was with difficulty I could see the lymphatic vesicles, till the membranes which cover the testicles were removed. The small quantity of liquor that was squeezed from the testicles contained no moving bodies.

EXPER. XXXIII.

In another bitch still younger, there was no appearance of glandulous bodies on the testicles; their surface was white, and perfectly smooth. Some small vesicles were discovered; but they seemed to contain no liquor. I compared these female testicles with those of a male of the same age, and found that their internal texture, which was fleshy, was nearly of the same nature,

EXPER. XXXIV.

I procured the uterus of a cow that had been recently killed. It was brought to me in a basket, wrapped in warm cloths, along with a

live rabbit, to preserve it from cooling. The testicles were as large as a small hen's egg; on one of them was a glandulous body of the size of a pea, which protruded from the testicle like a little nipple: but it had no fissure or external aperture. It was so firm and hard, that I could not press any liquor out of it with my fingers. Before cutting this testicle, I observed two other glandulous bodies at a distance from each other. They were very small, and of a whitish yellow colour; but the large one, which seemed to have pierced the membrane of the testicle, was as red as a rose. I examined this last with great attention, but could discover no liquor; from which I concluded, that it was still far from being mature.

EXPER. XXXV.

In the other testicle, there were no glandulous bodies which had yet pierced the membrane that covers the testicle. Two small ones only began to appear under the membrane. I opened them both; but procured no liquor from them. They were hard bodies, with a tincture of yellow. On each testicle there were four or five lymphatic vesicles; they were full of liquor. When examined with the microscope, some small globules appeared; but there was not in them the least vestige of motion. I observed this liquor, from time to time, for two days, without discovering any thing new.

EXPER. XXXVI.

I had two other uteri conveyed to me in the same manner. The one belonged to a young cow that had never brought forth; the other to a cow which, though not old, had had several young. I first examined the testicles of the latter, and found, upon one of them, a glandulous body as large as a cherry. I perceived three holes, into which bristles might be introduced. Having pressed the body with my fingers, a small quantity of liquor issued out, which I examined, and had the pleasure of seeing moving bodies (pl. xii. fig. 22), but different from what I had observed in other seminal fluids. These globules were small and obscure: their progressive motion, though distinct, was very slow. The liquor was not thick: the moving globules had no appearance of threads or tails, and they were not all in motion. These are all the observations I could make on this liquor; for, though I again squeezed the glandulous body, I could not obtain any more liquor that was unmixed with blood. The moving bodies were at least a fourth part less than the globules of the blood.

EXPER. XXXVII.

This glandulous body was situated at one extremity of the testicle, near the horn of

the uterus; and the liquor which it distilled must have fallen upon that horn: but, after opening the horn, I found no liquor. I then opened the testicle longitudinally, and, though its cavity was considerable, it contained no fluid. At some distance from the large glandulous body, there was a small one of the same kind, about the size of a lentil. Two cicatrices, or little pits, also appeared; they were of a deep red colour, and were the relics of old glandulous bodies which had been obliterated. Having next examined the other testicle of the same cow, I discovered four cicatrices and three glandulous bodies, the most advanced of which was of a red flesh-colour, and exceeded not the size of a pea. It was solid, without any aperture, and contained no liquor. The other two were much smaller and harder; and their colour was a kind of orange. The lymphatic vesicles were full of a clear liquid; but contained nothing that had the appearance of life.

EXPER. XXXVIII.

I then inspected the testicles of the young cow, which had never brought forth. They were rather larger than those of the other cow; but, what is not less remarkable than true, there was not a single cicatrice on either of them. A number of lymphatic vesicles appeared on one of the testicles; but there was no vestige of glandulous bodies. Upon the other testicle, I could

discern the rudiments of two glandulous bodies, one just beginning to spring up, the other as large as a small pea. There were also many vesicles, which appeared, after being pierced with a lancet, to contain nothing. The glandulous bodies, when opened, gave forth nothing but blood.

EXPER. XXXIX.

I cut each testicle of both cows into four parts, and, having put them into separate phials, I poured as much water upon them as was just sufficient to cover them; and, after corking the phials close, I allowed them to infuse for six days. I then examined the infusions with the microscope, and saw an amazing number of moving globules (pl. xii. fig. 23). In all the infusions, the globules were extremely small, but very active, moving with rapidity round their centres, and in all directions. I observed them, from time to time, during three days, and they always became smaller and smaller, till they totally disappeared on the third day.

EXPER. XL.

I procured the uteri of three other cows. I first searched the testicles in order to discover if there were any mature glandulous bodies. In two of the uteri I found only small glandulous

bodies on the testicles. I was not informed whether the cows had ever brought forth; but it is probable that they had often been in season; for a number of cicatrices appeared on their testicles. On one of the testicles of the third cow, I observed a glandulous body as large as a cherry, and very red; it was much swelled, and seemed to be perfectly ripe. I pressed the nipple, which was perforated by a hole, with my fingers, and a considerable quantity of liquor issued out. In this liquor, I found moving bodies (pl. xii. fig. 24) perfectly similar to those described in exper. xxxvi.[1] Their number was indeed greater, and their progressive motion was quicker; they seemed to be somewhat longer; and, having observed them a long time, I perceived that they grew longer, and changed their figure. I then introduced a fine probe into the small aperture of the glandulous body; and, having cut along the probe as a directory, I found that the cavity was filled with a liquid matter. This liquor, when examined with the microscope, presented the same phænomena, the same moving bodies, as in exper. xxxvi. But I could discover in none of them either filaments or tails. The liquor of the vesicles was still transparent, and contained nothing like life or motion.

EXPER. XLI.

The uteri of several other cows were brought to me at different times. In the testicles of some

Plate 12

Fig. 19.

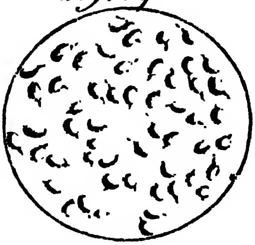


Fig. 20.

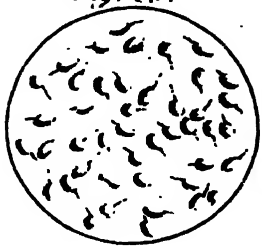


Fig. 21.

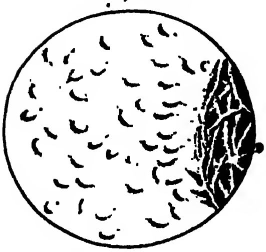


Fig. 22.

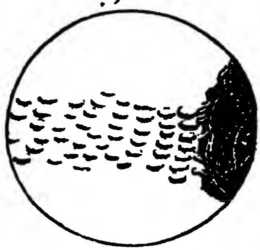


Fig. 23.

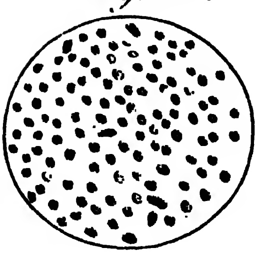
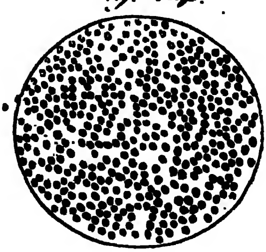


Fig. 24.



of them, there were glandulous bodies almost ripe; in those of others, they were in different states of growth; and I perceived nothing new or uncommon, except that I discovered, in the testicles of two of them, glandulous bodies in a decayed state, the base of one of which was as large as the circumference of a cherry. The extremity of the nipple was soft and withered: the two small holes through which the fluid had issued were still visible. I introduced a small bristle into them; but there was no liquor, either in the canal, or in the internal cavity, which could still be distinguished. The extinction of the glandulous bodies, therefore, commences at the most external part or extremity of the nipple. They first diminish in height, and then in breadth, as I had an opportunity of observing in another testicle, where there was a glandulous body diminished about three fourths.

EXPER. XLII.

As the testicles of female rabbits, as well as their glandulous bodies, are very minute, I could make no exact experiments on their seminal liquor. I only discovered, that the testicles of different females are in different states; and that I never saw any of them which exactly resembled De Graaff's figures.

EXPER. XLIII.

On the testicles of some cows, I found a species of bladders or vesicles, which are called *hydatides* by anatomists. I observed some of them large, and others small; and they were attached to the testicle by a kind of pedicle. I examined the liquor they contained; but it was transparent, homogeneous, and every way similar to the liquor in the vesicles. It had no globular or moving particles.

EXPER. XLIV.

At this time, I made some experiments upon oyster water, upon water in which pepper had been boiled, upon water in which pepper had been simply infused, and upon water in which pink-seeds were infused. The bottles containing all these infusions were exactly corked. At the end of two days, I saw, in the oyster water, a vast quantity of oval and globular bodies, which seemed to swim like fishes in a pond, and had every appearance of being real animals. They had no members that could be discovered, and no tails. They were transparent, and pretty large; I saw them change their figures; they became gradually smaller and smaller during the seven or eight days that they existed; and, lastly, along with Mr. Needham, I saw animalcules so very similar, in an infusion of the jelly

of roasted veal, which had likewise been close corked, that I am persuaded they are not true animals, agreeable to the common acceptation of that term, as shall afterwards be fully explained

The infusion of pink-seeds was crowded with innumerable moving globules, which appeared to be equally animated with those in the seminal liquors and infusions of flesh. At first they were pretty large, and moved with great rapidity in every possible direction. They continued in this state during three weeks, and gradually diminished in size till their minuteness rendered them invisible.

The same phænomenon took place in the infusions of pepper; but the moving bodies did not appear so early as in the other infusions, and their appearance was later in the infusion of pepper that was not boiled. I then began to suspect that what is called fermentation, might be owing to the motion of these organic particles in animal and vegetable substances. To discover if there was any similarity between this species of fermentation, and that excited by mineral substances, I applied to the microscope a little limestone powder, and poured upon it a drop of aquafortis. But the phænomena were totally different. Large bubbles rose to the surface, and instantly darkened the lens of the microscope; when the gross parts were dissolved, every thing remained at rest, and nothing appeared which had the smallest analogy to what we perceive in the infusions of animal or vegetable substances.

EXPER. XLV.

I examined the seminal liquor in the milts of different fishes, extracted while the animals were alive; and I observed a vast quantity of obscure moving globules. I then squeezed with my fingers the aperture in the bellies of fishes through which they emit this liquor; and, in the drops which I procured, I saw great multitudes of the same moving globules, which were almost black, and very small.

EXPER. XLVI.

Before I conclude this chapter, I shall relate the experiments of Mr. Needham upon the semen of a species of cuttle-fish, called the calmar. This acute observer having examined the spermatic animals in the milts of different fishes, found them of an uncommon magnitude in the milt of the calmar. To the naked eye, they were from three to four lines in length. During a whole summer, while he dissected calmars at Lisbon, he could find no appearance of a milt, or of any reservoir destined to receive the seminal liquor of that fish; and it was the middle of December before he could perceive the first vestiges of a new vessel filled with a milty juice. This reservoir, and the juice it contained, gradually increased. In examining this seminal li-

quor with a microscope, he saw nothing in it but small opaque globules, swimming in a kind of serous matter, without any appearance of life. But, some time after, he discovered, in the milt of another calmar, organic bodies completely formed, which resembled spiral springs (*a*, *b*, pl. xiii. fig. 2.), inclosed in a transparent case. These springs were equally perfect at the first observation as afterwards; only they, in time, contracted themselves, and formed a kind of screw. The head of the case is a species of valve, which opens outward, and through which every thing within may be forced out. It contains, besides, another valve, *b*, a little barrel, *c*, and a spongy substance, *d*, *e*. Thus the whole machine consists of an outer, transparent, cartilaginous case (*a*, fig. 2), the superior extremity of which is terminated by a round head, formed by the case itself, and performs the office of a valve. This internal case contains a transparent tube, which includes the spring, a piston or valve, a little barrel, and a spongy substance. The screw occupies the superior part of the tube and case, the piston and barrel are situated in the middle, and the spongy substance occupies the inferior part. These machines pump the liquor of the milt; the spongy substance is full of this liquor; and, before the animal spawns, the whole milt is only a congeries of these organic bodies, which have absolutely pumped up and dried the milty liquor. Whenever these small machines are taken from the body of the animal, and put among water, or exposed to the air, they begin

to act (pl. xiii. fig. 2 and 3); the spring mounts up, and is followed by the piston, the barrel, and the spongy substance which contains the liquor; and, as soon as the spring and the tube, in which it is contained, begin to issue out of the case, the spring plaits, and the whole internal apparatus moves, till the spring, the piston, and the barrel, have entirely escaped from the case. When this is effected, all the rest instantly follow, and the milty liquor, which had been pumped, and was confined in the spongy substance, runs out through the barrel.

As this phænomenon is extremely singular, and incontestibly proves that the moving bodies in the milt of the calmar are not real animals, but simple machines, a species of pumps, I shall here transcribe Mr. Needham's own account of the matter:

"When the small machines *," says he, "have come to their full maturity, several of them act as soon as they are exposed to the air. Most of them, however, may be commodiously viewed by the microscope before their action commences; and, even before they act, it is necessary to moisten with a drop of water the superior extremity of the external case, which then begins to expand, while the two slender ligaments, that issue out of the case, are twisted and contorted in different ways. At the same time the screw rises slowly, and the spirals at its superior end

* Needham's New Discoveries made with the Microscope, chap. vi. p. 53.

approach each other, and act against the top of the case, those which are lower seeming to be continually followed by others that issue from the piston; I say, that they *seem* to follow; because I believe it to be only a deception produced by the motion of the screw. The piston and barrel likewise move in the same direction; and the inferior part, which contains the semen, extends in length, and, at the same time, moves towards the top of the case, which is apparent by the vacuity left at the bottom. As soon as the screw, with the tube in which it is inclosed, begins to appear out of the case, it twists, because it is constrained by the two ligaments. The whole internal apparatus continues to move gradually and slowly, till the screw, the piston, and the barrel, have entirely escaped. When that happens, the remainder issues instantaneously. The piston, *b* (pl. xiii. fig. 2), separates from the barrel *a*; the ligament, which is under the barrel, swells and acquires a diameter equal to that of the spongy part which succeeds it: this, though much broader than when in the case, becomes also five times longer than formerly. The tube, which included the whole, contracts in the middle, and forms two knots or joints, *d*, *e* (pl. xiii. fig. 2 and 3), distant about one third of its length from each extremity. Then the semen escapes by the barrel *e* (fig. 2). It is composed of small opaque globules, which swim in a serous matter, without discovering any signs of life, and are precisely the same as I perceived them to be

when diffused through the reservoir of the milt. In the figure, the part comprehended between the two joints *d*, *e*, appears to be fringed. When examined attentively, this appearance seems to be occasioned by the spongy substance within the tube being broken and divided into portions nearly equal. The following phænomena will clearly prove that this is the case.

"It sometimes happens, that the screw and the tube break precisely above the piston *b*, which remains in the barrel *c* (fig. 3). Then the tube instantly shuts; and, by contracting, assumes a conical figure above the extremity of the screw, *f*. This is a demonstration that it is there very elastic; and the manner in which it accommodates its figure to that of the substance which includes it, when the latter undergoes the smallest change, proves that it is every where equally elastic."

Mr. Needham hence concludes, that it is natural to imagine that the total action of this machine is occasioned by the spring of the screw. But, unfortunately, he proves, by several experiments, that the screw is acted upon by a power residing in the spongy part: as soon as the screw is separated from the rest of the machine, it ceases to act, and loses all motion. The author draws the following conclusion from this singular phænomenon.

"*If I had seen*," says he, "these pretended animalcules in the semen of living animals, I should, perhaps, have been able to ascertain

whether they are really animated beings, or only prodigiously small machines, which correspond in miniature to the larger vessels of the calmar."

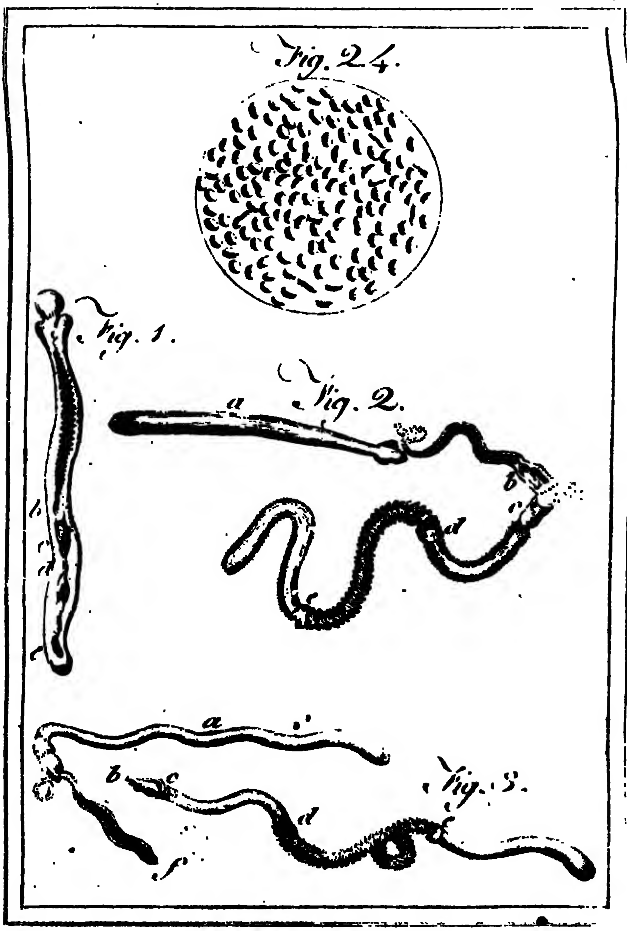
From this and other analogies, Mr. Needham concludes, that the spermatic worms of other animals, it is reasonable to think, are only organic bodies; a species of machines similar to those of the calmar, which act at different times; for, says he, if we suppose that, of the prodigious number of spermatic animalcules which appear in the field of the microscope, only a few thousands act at a time, this will be sufficient to make us believe the whole to be alive. If it be farther supposed, he adds, that the motion of each animalcule lasts, like that of the calmar machines, about half a minute; in this case, the successive action of the small machines would continue for a considerable time, and the animalcules would die one after another. Besides, why should the semen of the calmar alone contain machines, while that of all other animals contains real living animalcules? Here the analogy is so strong as to be almost irresistible. Mr. Needham farther remarks, that even Leeuwenhoek's experiments seem to indicate that the spermatic animals have a great resemblance to the organic bodies in the semen of the calmar. Speaking of the semen of the cod, Leeuwenhoek remarks, that he imagined the oval bodies to be animalcules burst and distended, because they were four times larger than when alive. And, in another place, he observes of the semen

of a dog, that the animalcules often changed their figure, especially when the liquor began to evaporate *.

On all these accounts, Mr. Needham conjectured, that the pretended spermatic animals were only a kind of natural machines, bodies much more simply organized than those of real animals. I examined the machines of the calmar along with him, and the reader may be assured that his description of them is both exact and faithful. His experiments, therefore, demonstrate, that the seminal fluid consists of particles in quest of organization; that, in fact, it produces organized bodies; but that these bodies are not animals, nor similar to the individual which produces them. It is indeed probable, that these organized bodies are only a kind of instruments for perfecting the semen, and bestowing on it an active force; and that it is by their internal action that they intimately penetrate the seminal fluid of the female.

* See Leeuwenh. Arc. Nat. p. 306, 309, and 319.

Plate 13



CHAP. VII.

Comparison of my own Experiments with those of Leeuwenhoek.

THOUGH my experiments were made with all the attention of which I was capable, and though I often repeated them, I am satisfied that many things must have escaped me. I have described only what I saw, and what every man may see, at the expense of a little art and patience. To free myself from prejudice, I even attempted to forget what other observers pretended to have seen, endeavouring, by this means, to be certain of seeing nothing but what really appeared; and it was not till I had digested my experiments, that I wished to compare them with those of former Writers, and particularly with those of Leeuwenhoek, who had occupied himself more than sixty years in experiments of this kind.

Whatever authority may be due to this acute observer, it is certainly allowable to institute a comparison between a man's own observations, and those of the most respectable writer on the same subject. By an examination of this kind, truth may be established, and errors may be detected, especially when the only object of in-

quiry is to ascertain the genuine nature of those moving bodies which appear in the seminal fluids of all animals.

In the month of November, 1677, Leeuwenhoek, who had formerly communicated many microscopic observations to the Royal Society of London, concerning the juices of plants, the texture of trees, the optic nerve, rain water, &c., writes to lord Brouncker, president of the Society, in the following terms: "Postquam * Exc. Dominus Professor Cranen me visitatione sua sæpius honorarat, litteris rogavis Domino Ham cognato suo, quasdam observationum mearum videndas darem. Hic Dominus Ham me secundo invisens, secum in laguncula vitrea semen viri, gonorrhœa laborantis, sponte destillatum, attulit, dicens, se post paucissimas temporis minutas (cum materia illa jam in tantum esset resoluta ut fistulæ vitreæ immitti posset), animalcula viva in eo observasse, quæ caudam et ultra 24 horas non viventia judicabat: idem referebat se animalcula observasse mortua post sumptam ab ægroto therebintinam. Materiam prædicatam fistulæ vitreæ immissam, præsente Domino Ham, observavi, quasdamque in ea creaturas viventes, ac post decursum 2 aut 3 horarum eamdem solus materiam observans, mortuas vidi.

"Eamdem materiam (semen virile) non ægroti alicujus, non diuturna conservatione corruptam, vel post aliquot momenta fluidiorem

* See Phil. Trans. num. 141, p. 1041.

factam, sed sani viri statim post ejectionem, ne interlabentibus quidem sex arteriæ pulsibus, sæpiuscule observavi, tantamque in ea viventium animalculorum multitudinem vidi, ut interdum plura quam 1000 in magnitudine arenæ sese moverent; non in toto semine, sed in materia fluida crassiori adhærente, ingentem illam animalculorum multitudinem observavi; in crassiori vero seminis materia quasi sine motu jacebant, quod inde provenire mihi imaginabar, quod materia illa crassa ex tam variis cohæreat partibus, ut animalcula in ea se movere nequirent; minora globulis sanguini ruborem adferentibus hæc, animalcula erant, ut judicem, millena millia arenam grandiorem magnitudine non æquatura. Corpora eorum rotunda, anteriora obtusa, posteriora ferme in aculeum desinentia habebant; cauda tenui longitudine corpus quinquies sexiesve excedente, et pellucida, crassitiem vero ad 25 partem corporis habente, prædita erant, adeo ut ea quo ad figuram cum cyclaminis minoribus, longam caudam habentibus, optime comparare queam: motu caudæ serpentino, aut ut anguillæ in aqua natantis, progrediebantur; in materia vero aliquantulum crassiori caudam octies deciesve quidem evibrabant antequam latitudinem capilli procedebant. Interdum imaginabar me internoscere posse adhuc varias in corpore horum animalculorum partes, quia vero continuo eas videre nequibam, de iis tacebo. His animalculis minora adhuc animalcula, quibus non

nisi globuli figuram attribuere possum, permista erant.

"Memini me, ante tres aut quatuor annos, rogatu Domini Oldenburg B. M. semen verile observasse, et prædicta animalia pro globulis habuisse; sed quia fastidiebam ab ulteriori inquisitione, et magis quidem a descriptione, tunc temporis eam omisi. Jam quoad partes ipsas, ex quibus crassam seminis materiam, quoad majorem sui partem consistere sæpius cum admiratione observavi, ea sunt tam varia ac multa vasa, imo in tanta multitudine hæc vasa vidi, ut credam me in unica seminis gutta plura observasse quam anatomico per integrum diem subjectum aliquod secanti occurrant. Quibus visis, firmiter credebam nulla in corpore humano jam formato esse vasa, quæ in semine virili bene constituto non reperiantur. Cum materia hæc per momenta quædam aëri fuisset exposita, prædicta vasorum multitudo in aquosam magnis oleaginosis globulis permistam materiam mutabatur," &c.

The secretary of the Royal Society replied to this letter of Leeuwenhoek, that it would be proper to make similar experiments on the seminal fluids of other animals, not only to support the original discovery, but to distinguish whatever differences might appear in the number and figure of the animalcules: and, with regard to the vascular texture of the thick part of the seminal fluid, he suspected that it was only a congeries of filaments, without any regular orga-

nization: "Quæ tibi videbatur vasorum congeries, fortassis seminis sunt quædam filamenta, haud organice constructa, sed dum permearunt vasa generationi inservientia in istiusmodi figuram elongata. Non dissimili modo ac sæpius notatus sum salivam crassiorem ex glandularum faucium foraminibus editam, quasi e convolutis fibrillis constantem *."

Leeuwenhoek replied, 18th March, 1678, in the following words: "Si quando canes coeunt marem a fœmina statim seponas, materia quædam tenuis et aquosa (lympha scilicet spermatica) a pene solet paulatim extillare; hanc materiam numerosissimis animalculis repletam aliquoties vidi, eorum magnitudine quæ in semine virili conspiciuntur, quibus particulæ globulares aliquot quinquagies majores permiscebantur.

"Quod ad vasorum in crassiori seminis virilis portione spectabilium observationem attinet, denuo non semel iteratam, saltem mihimetipsi comprobasse videor; meque omnino persuasum habeo, cuniculi, canis, felis, arterias venasve fuisse a peritissimo anatomico haud unquam magis perspicue observatas, quam mihi vasa in semini virili, ope perspicilli, in conspectum venere.

"Cum mihi prædicta vasa primum innotuere, statim etiam pituitam, tum et salivam perspicillo applicavi; verum hic minime existentia animalia frustra quæsivi.

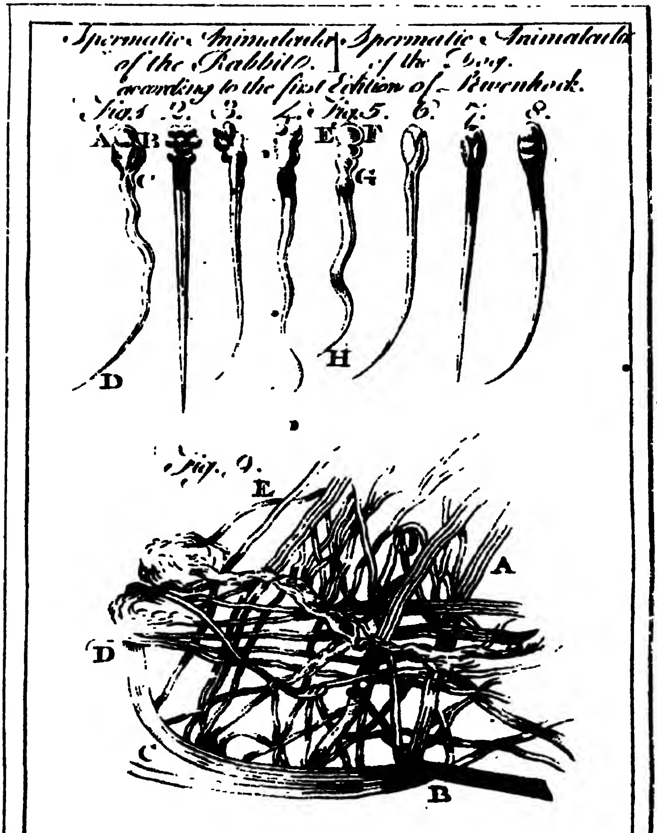
* See Phil. Trans. num. 141, p. 1043.

"A cuniculorum coitu lymphæ spermaticæ guttulam unam et alteram, e femella extillantem, examini subjeci, ubi animalia prædictorum similia, sed longe pauciora, comparuere. Globuli item quam plurimi, plerique magnitudine animalium, iisdem permisti sunt.

"Horum animalium aliquot etiam delineationes transmisi; figura, 1. (pl. xii. fig. 1) exprimit eorum aliquot vivum (in semine cuniculi arbitror) eaque forma qua videbatur, dum aspicientem me versus tendit. A B C, capitulum cum trunco indicant; C D, ejusdem caudam, quam pariter ut suam anguilla inter natandum vibrat. Horum millena millia, quantum conjectare est, arenulæ majoris molem vix superant. (Pl. xii. fig. 2, 3, 4) sunt ejusdem generis animalia, sed jam emortua.

"(Pl. xii. fig. 5) delineatur vivum animalculum que madmodum in semine canino sese aliquoties mihi attentius intuenti exhibuit. E F G, caput cum trunco indigitant, G H, ejusdem caudam. (Pl. xii. fig. 6, 7, 8.) Alia sunt in semine canino quæ motu et vita privantur, qualium etiam vivorum numerum adeo ingentem vidi, ut judicarem portionem lymphæ spermaticæ arenulæ mediocri respondentem, eorum ut minimum decena millia continere."

In another letter to the Royal Society, dated May 31, 1678; Leeuwenhoek adds, "Seminis canini tantillum microscopio applicatum iterum contemplatus sum, in eoque antea descripta animalia numerosissime conspexi. Aqua pluvialis pari quantitate adjecta, iisdem confestim mor-


Spermatic Animalcula
of the Rabbit.
Spermatic Animalcula
according to the first Edition of
Fig. 1
2.
3.
4.
Fig. 5.
6.
7.
8.
A
B
C
D
E
F
G
H
Fig. 9.
E
A
D
C
B

tem accercit. Ejusdem seminis canini portiuncula in vitreo tubulo unciæ partem duodecimalem crasso servata, sex et triginta horarum spatio contenta animalia vita destituta pleraque, reliqua moribunda videbantur.

"Quo de vasorum in semine genitali existentia magis constaret, delineationem aliqualem mitto, ut in figura ABCDE (pl. xii. fig. 9) quibus literis circumscriptum spatium arenulam mediocrem vix superat."

I have transcribed these passages from the Philosophical Transactions, because they first appeared in that work, before Leeuwenhoek had formed any theory; and, therefore, they must be more agreeable to truth. After the ingenious author had formed a system of generation, his account of the spermatic animals varies, even in essential articles*.

In the first place, what he says concerning the number of these pretended animalcules is true; but the figure of their bodies corresponds not always to his description. Sometimes the end next the tail is globular, and sometimes cylindrical; sometimes it is flat, and at other times it is broader than long, &c. With regard to the tail, it is often thicker and shorter than he represents. The vibratory motion he ascribes to the tail, and by which he alleges the animals

* Here the author attempts a formal proof that Leeuwenhoek invented the single microscope, and discovered the existence of spermatic animals, before Hartsoeker, which interrupts the argument, is nowise interesting to the reader, and therefore I have here omitted it in the translation.

are enabled to proceed forward, I never could distinguish in the manner he describes. I have seen these moving bodies vibrate eight or ten times, from right to left, or from left to right, without advancing the breadth of a single hair: and I have observed many of them which never could proceed forward, because this tail, in place of assisting them to swim, was, on the contrary, a small thread attached to the filaments or mucilaginous part of the liquor, and, of course, totally prevented the progressive motion of the body. Even when the tail appeared to have any motion, it resembled only the small bendings of a thread at the end of a vibration. I have seen these threads or tails fixed to the filaments, which Leeuwenhoek calls vessels:* I have seen them separate from the filaments after repeated efforts made by the moving bodies: I have seen them first long, then diminish, and at last disappear. Thus these tails ought to be regarded as accidental appendages, and not as real members of the moving bodies. But, what is more remarkable, Leeuwenhoek expressly affirms, in his letter to lord Brouncker, that, besides the tailed animals, he observed in this liquor animalcules still more minute, that had no tails, and were perfectly globular: "His animalculis (caudatis scilicet) minora adhuc animalcula, quibus non nisi globuli figuram attribuere possum, permista erant." This is the truth. After Leeuwenhoek, however, had maintained that these animalcules were the only efficient principle of generation, and that they were transformed into men, he re-

gards as real animals those only which had tails; and, accordingly, as it was necessary that animalcules, to be transformed into men, should have a constant and invariable figure, he never afterwards mentions the round animals without tails. I was struck with the difference between the original composition of this letter, and the form in which it appeared twenty years afterwards in his third volume: for, instead of the words which we have just now quoted, we meet with the following in page 63: "Animalculis hisce permistæ jacebant aliæ minutiores particulæ, quibus non aliam quam globulorum seu sphæricam figuram assignare queo." This is a very different account of the matter. A particle of matter, to which he ascribes no motion, is extremely different from an animalcule. It is astonishing that Leeuwenhoek, in copying his own letter, should have changed an article of so much consequence. What he immediately subjoins likewise merits attention. He says, that, at the entreaty of Mr. Oldenburg, he had examined this liquor three or four years ago; and that he then imagined these animalcules to be globules. Thus, these pretended animalcules are sometimes globules without any sensible motion; sometimes they are globules which move with great activity; sometimes they have tails, and sometimes no tails. Speaking of spermatic animals in general, he remarks*, "Ex hisce meis observationibus

* Tom. iii. p. 371.

cogitare cœpi, quamvis antehac, de animalculis in seminibus masculinis agens, scripserim me in illis caudas non detexisse, fieri tamen posse ut illa animalcula æque caudis fuerint instructa, ac nunc comperi de animalculis in gallorum gallinaceorum semine masculino:" another proof that he has often seen spermatic animals, of all kinds, without tails.

Secondly, It is worthy of remark, that Leeuwenhoek had very early discovered the filaments which appear in the semen before it be liquified; and that, at that time, when he had not conceived his hypothesis concerning the spermatic animals, he imagined the filaments to be veins, nerves, and arteries. He firmly believed, that all the parts and vessels of the human body might be clearly distinguished in the seminal fluid. He even persisted in this opinion, notwithstanding the representations made to him by Mr. Oldenburg, in the name of the Royal Society. But, after he conceived the notion of transforming his spermatic animals into men, he never again takes any notice of these vessels. Instead of regarding them as the nerves and blood vessels of the human body already formed in the semen, he does not even ascribe to them their real function, which is the production of the moving bodies. He observes *, "Quid fiet de omnibus illis particulis seu corpusculis præter illa animalcula semini virili hominum inhæren-

* Tom. i. p. 7.

tibus! Olim et priusquam hæc scriberem, in ea sententia fui prædictas strias vel vasa ex testiculis principium secum ducere," &c. And, in another place, he says, that what he had formerly remarked concerning vessels in the semen deserved no attention.

Thirdly, If we compare the figures 1, 2, 3, and 4, plate xiv. xv. which we have represented exactly as they appear in the Philosophical Transactions, with those which Leeuwenhoek caused to be engraved several years after, we shall find very great differences, especially in those of the dead animalcules of the rabbit, 1, 3, and 4, and in those of the dog, which I have also delineated, in order to give a distinct idea of the matter. From all this, it may fairly be concluded, that Leeuwenhoek has not always seen the same phænomena; that the moving bodies, which he regards as animals, have appeared to him under different forms; and that he has contradicted himself with a view to make the species of men and of animals uniform and consistent. He not only varies as to the fundamental part of these experiments, but also as to the manner of making them; for he expressly tells us, that he always diluted the semen with water, to separate its parts, and to give more freedom of motion to the animalcules*; and yet, in his first letter to lord Brouncker, he says, that, when he mixed the semen of dogs, in which he before had seen innumerable animals, with water, they all instantly

* Tom. iii. p. 92, 93.

died. Thus Leeuwenhoek's first experiments were made, like mine, without any mixture; and it appears, that he did not mix the liquor with water till long after he began his experiments, and till he conceived the idea that water killed the animalcules; which, however, is not true; I imagine that the addition of water only dissolves the filaments too suddenly; for, in all my experiments, I have seen but very few filaments in the liquor, after its being mixed with water.

Leeuwenhoek was no sooner persuaded that the spermatic animalcules were transformed into men and other animals, than he imagined that he saw two distinct kinds in the semen of every animal, the one male and the other female. Without this difference of sex in the spermatic animalcules, it was difficult, he says, to conceive the possibility of producing males and females by simple transformation. He mentions these male and female animalcules in his letter published in the Philosophical Transactions, No. 145, and in several other places *. But he attempts not to describe the differences between the male and female animalcules, which never existed but in his own imagination.

The famous Boerhaave having asked Leeuwenhoek, whether he had observed any differences in the growth and size of spermatic animals? Leeuwenhoek replied, that, in the semen of a rabbit which he had opened, he saw an in-

* See tom. i. p. 163, and tom. iii. p. 101, of his works.

finite number of animalcules: "Incredibilem," says he, "viventium animalculorum numerum conspexerunt, cum hæc animalcula scypho imposita vitreo et illic emortua, in rariores ordines disparessent, et per continuos aliquot dies sæpius visu examinassem, quædam ad justam magnitudinem nondum excrevisse adverti. Ad hæc quasdam observavi particulas perexiles et oblongas, alias aliis majores, et, quantum oculis apparebat, cauda destitutas; quas quidem particulas non nisi animalcula esse credidi, quæ ad justam magnitudinem non excrevissent*." Here we have animalcules of different sizes, and some with tails, and others that had no tails, which better correspond with my experiments than with Leeuwenhoek's system. We only differ in a single article. He considers the oblong bodies without tails as young animalcules, which have not yet arrived at their full growth: but I, on the contrary, have seen these pretended animals originally spring from the filaments with their tails or threads, which they gradually lost.

In the same letter to Boerhaave he says†, that, in the semen of a ram he observed the animalcules marching in flocks, like sheep: "A tribus circiter annis testes arietis, adhuc calentes, ad ædes meas deferri curaveram; cum igitur materiam ex epididymibus eductam, ope microscopii contemplarer, non sine ingente voluptâte

* See tom. iv. p. 280, 281.

† Tom. iv. p. 28.

adverteham animalcula omnia, quotquot innatabant semini masculino, eundem natando cursum tenere, ita nimirum ut quo itinere priora prænatârent, eodem posteriora subsequerentur, adeo ut hisce animalculis quasi sit ingenitum, quod oves factitare videmus, scilicet ut præcedentium vestigiis grex universus incedat." This observation, made by Leeuwenhoek in the year 1713, and which he regarded as new and singular, is a sufficient proof that he had never so attentively examined the seminal fluids of animals as to enable him to give exact descriptions of them. In the year 1713, he was seventy-one years of age: he had been in the constant practice of making experiments with the microscope for forty-five years: he continued to publish his observations during thirty-six years: and yet, after all his practice, he now, for the first time, observed a phænomenon which is exhibited in every semen, and which I have described, exper. ix. in the human semen, exper. xii. in the semen of a dog, and exper. xxix. in the semen of a bitch. To explain the moving of the animalcules of the ram in flocks, therefore, it is unnecessary to suppose them endowed with the natural instinct peculiar to sheep; since those of man, of the dog, and of the bitch, move in the very same manner; and since this motion depends upon particular circumstances, the principal of which is, that the fluid part of the semen should be on one side, and the thick or filamentous part on the other; for then the whole moving bodies

disengage themselves from the filaments, and proceed, in the same direction, into the more fluid part of the liquor.

In another letter, written the same year, and addressed to Boerhaave*, he relates some farther observations concerning the semen of the ram: he tells us, that, when the liquor was put into separate glasses, and examined, he observed flocks of animalcules moving all in the same direction, and other flocks returning the contrary way. He adds: "Neque illud in unica epididymum parte, sed et in aliis quas præcideram partibus, observavi. Ad hæc, in quadam parastatarum resecta portione complura vidi animalcula, quæ necdum in justam magnitudinem adoleverant; nam et corpuscula illis exiliora et caudæ triplo breviores erant quam adultis. Ad hæc, caudas non habebant desinentes in mucronem, quales tamen adultis esse passim comperio. Præterea, in quandam parastatarum portionem incidi, animalculis, quantum discernere potui, destitutam, tantum illi quædam perexiguæ inerant particulæ, partim longiores partim breviores; sed altera sui extremitate crassiunculæ; istas particulas in animalcula transituras esse non dubitabam." From this passage it is apparent, that Leeuwenhoek had seen, in this seminal liquor, what I have found in the semen of all the animals which I examined, moving bodies that differed in size, figure, and motion; and these circumstances, it is obvious, correspond better with the

* See tom iv. p. 304.

notion of organic particles in motion, than with that of real animals.

It appears, therefore, that Leeuwenhoek's observations, though he draws very different conclusions from them, perfectly correspond with mine: and, though there be some opposition in the facts, I am fully persuaded, that, whoever shall take the trouble of repeating the experiments, will easily discover the source of these differences, and find that I have related nothing but truth. To enable the reader to decide in this matter, I shall add a few remarks:

We do not always see, in the human semen, the filaments I have mentioned: for this purpose, the liquor must be examined the moment it is extracted from the body; and even then they do not uniformly appear. When the liquor is too thick, it presents nothing but large globules, which may be distinguished with a common lens. When examined with the microscope, they have the appearance of small oranges; they are very opaque, and one of them occupies the whole field of the microscope. The first time I observed these globules, I imagined them to be foreign bodies which had fallen into the liquor. But, after examining different drops, I found that the whole liquor was composed of these large globules. I observed one of the largest and roundest of them for a long time. At first it was perfectly opaque: a little after, I perceived on its surface, about half way between the centre and circumference, a beautiful coloured luminous ring, which continued more

than half an hour, then gradually approached the centre, which became clear and coloured, while the rest of the globule remained opaque. This light, which illuminated the centre, resembled that which appears in large air-bubbles. The globule now began to grow flat, and to have a small degree of transparency: and, after observing it for three hours, I could perceive no other change, no appearance of motion, either internal or external. I imagined that some change might happen by mixing the liquor with water. The globules were indeed changed into a transparent, homogeneous fluid, which presented nothing worthy of remark. I left the semen to liquify of its own accord, and examined it at the distance of six, twelve, and twenty-four hours; but found nothing like life or motion. I relate this experiment to show, that the ordinary phænomena are not always to be expected in seminal fluids, though they be apparently similar.

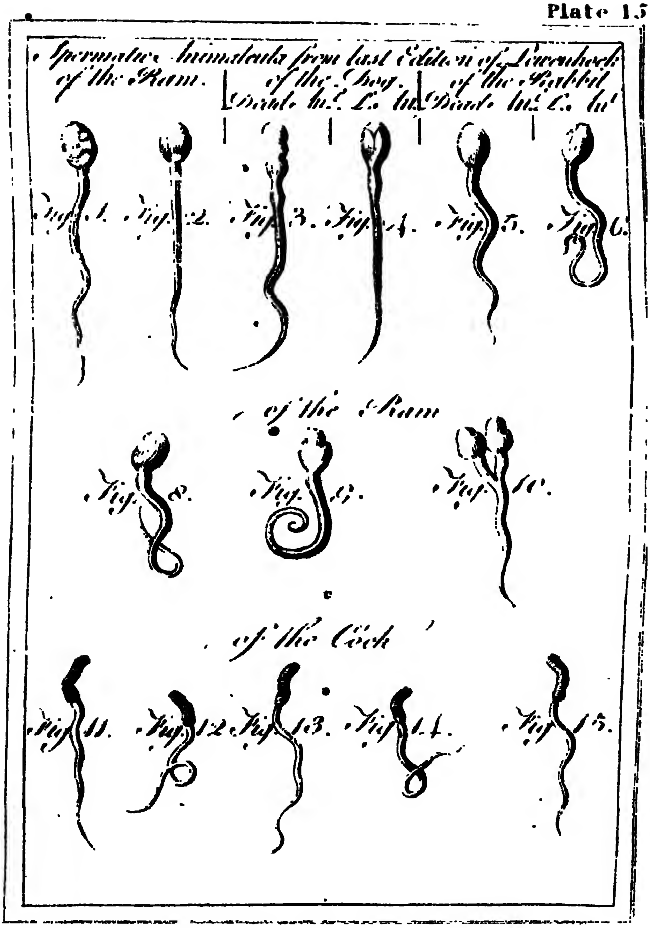
Sometimes all the moving bodies have tails, especially in the semen of man, and of the dog; their motion is not then very rapid, and appears to be performed with difficulty. If the liquor be allowed to dry, the tails or threads are first deprived of motion; the anterior extremity continues to vibrate for some time, and then all motion ceases. These bodies may be long preserved in this state; and, if a small drop of water be then poured upon them, their figure changes; they fall down into several minute globules, which appear to have a small degree of motion,

sometimes approaching each other, and sometimes trembling, and turning round their centres.

The moving bodies in the human semen, and in those of the dog and bitch, resemble each other so strongly, that it is not easy to distinguish them, especially when examined immediately after they are taken from the body of the animal. Those of the rabbit appear to be smaller and more active. But these differences and resemblances proceed more from the different states of the fluids during the time of examination, than from the nature of the fluids themselves, which ought indeed to be different in different species of animals: for example, in the human fluid, I have remarked large filaments, as represented in pl. iii. fig. 3, &c., and I have seen the moving bodies separate from these filaments, from which they appeared to derive their origin. But I could perceive nothing of this kind in the semen of the dog. Instead of distinct filaments, it is generally composed of a compact mucilage, in which we with difficulty perceive some filamentous parts; and yet this mucilage gives birth to moving bodies similar to those in the human semen.

The motion of these bodies continues longer in the fluid of the dog, than in that of man, which enables us more easily to distinguish the change of form above remarked. The moment the fluid issues from the body of the animal, we find most of the animalcules possessed of tails. In twelve, twenty-four, or thirty-six hours afterwards, almost the whole tails disappear; we then perceive

Plate 15


Spermatic Animalcula from last Edition of Leeuwenhoek
of the Ram.
of the Dog.
of the Rabbit
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
of the Ram
Fig. 8.
Fig. 9.
Fig. 10.
of the Cock
Fig. 11.
Fig. 12.
Fig. 13.
Fig. 14.
Fig. 15.

only oval bodies moving about, and generally with more rapidity than at first.

The moving bodies are always below the surface of the liquor. Several large transparent air-bubbles commonly appear on the surface; but they have no motion, unless when the liquor is agitated. Below the moving bodies we often perceive others still more minute: these have no tails; but most of them move: and, in general, I have remarked, that, of the numberless globules in all these liquors, the smallest are generally blacker and more obscure than the others; and that those which are extremely minute and transparent have little or no motion. They seem likewise to have more specific gravity; for they are always sunk deepest in the fluid.

CHAP. VIII.

Reflections on the preceding Experiments.

FROM the foregoing experiments, it appears, that females, as well as males, have a seminal fluid containing bodies in motion; that these moving bodies are not real animals, but only organic living particles; and that these particles exist not only in the seminal fluids of both sexes, but in the flesh of animals, and in the seeds of vegetables. To discover whether all the parts of animals and all the seeds of plants contained moving organic particles, I made infusions of the flesh of different animals, and of the seeds of more than twenty different species of vegetables; and, after remaining some days in close glasses, I had the pleasure of seeing organic moving particles in all of them. In some they appeared sooner, in others later. Some preserved their motion for months, and others soon ceased to move. Some, at first, produced large moving globules, resembling animals, which changed their figure, split, and became gradually smaller. Others produced only small globules, whose motions were extremely rapid; and others produced filaments, which grew longer, seemed to vegetate, and then swelled, and poured out torrents of moving globules. But it is needless to give a detail of my

experiments on the infusions of plants, especially since Mr. Needham has published his excellent and numerous observations on this subject. To this able naturalist I have read over the preceding treatise; I have often reasoned with him on the resemblance between the moving bodies in infusions of the seeds of vegetables, and those in the seminal fluids of male and female animals. He thought my views well founded, and of sufficient importance to merit a farther discussion. He, therefore, began to make experiments on the different parts of vegetables; and I acknowledge, that he has brought the ideas I communicated to greater perfection than I could have done. Of this I could give many examples: but I shall confine myself to one, because I formerly pointed out the fact in question, which he describes in the following manner:

To ascertain whether the moving bodies which appear in infusions of flesh were real animals, or only, as I had imagined, organic moving particles, Mr. Needham thought that an examination of the jelly of roasted meat would determine the question; because, if they were animals, the fire would destroy them; and, if not, they would still be perceptible, in the same manner as when the flesh was raw. Having, for this purpose, taken the jellies of veal and of other kinds of roasted meat, he [illegible] in glasses filled with water, and carefully [illegible] the bottles. After some days infusion, [illegible] in the whole of the liquors an imme[illegible]ber of moving bodies. He showed me [illegible] these infusions, and,

among others, that of the veal jelly, which contained moving bodies very similar to those in the semen of man, the dog, and the bitch, after they had lost their tails or threads. Though they changed their forms, their motions were so similar to those of animals swimming, that, whoever saw them for the first time, or had been ignorant of what has been formerly remarked concerning them, would certainly have conceived them to be real animals. I shall only add, that Mr. Needham has established, by numberless experiments, the existence of moving organic particles in all the parts of vegetables, which confirms what I have alleged, and extends my theory concerning the composition and reproduction of organized beings.

It is apparent, then, that all animals, whether male or female, and every species of vegetable, are composed of living organic particles. These organic particles abound most in the seminal fluids of animals, and in the seeds of vegetables. Reproduction is effected by the union of these organic particles, which are detached from all parts of the animal or vegetable body, and are always similar to the particular species to which they belong; for their union could not be accomplished but by the intervention of an internal mould, which is the efficient cause of the figure of the animal or vegetable, and in which the essence, the unity, and the continuation of the species consist, and will invariably continue till the end of time.

But, before drawing general conclusions from

the system I have established, some objections must be removed, which will contribute still farther to illustrate the subject.

It will be demanded of me, why I deny these moving bodies to be animals, after they have uniformly been recognised as such by every man who has examined them? It may likewise be asked, how is it possible to conceive the nature of living organic particles, unless we allow them to be real animals? And to suppose an animal to be composed of lesser animals is nearly the same idea, as when we say that an organized body is composed of organic living particles. To these questions I shall endeavour to give satisfactory answers.

It is true, that almost all observers agree in regarding the moving bodies in the seminal fluid as real animals. But it is equally certain, both from my experiments and those of Mr. Needham upon the semen of the calmar, that these moving bodies are beings more simple and less organized than animals.

The word *animal*, in its common acceptation, represents a general idea, composed of particular ideas, which we derive from particular animals. All general ideas include many different ideas, which more or less approach or recede from one another; and, of course, no general idea can be precise or exact. The general idea we have formed of an animal, may be derived from the particular idea of a dog, of a horse, and of other animals, from the power of volition, which enables them to act according to their inclination,

and from the circumstances of their being composed of flesh and blood, from their faculty of choosing and of taking nourishment, from their senses, from the distinction of sexes, and from their power of reproducing. The general idea, therefore, expressed by the word *animal*, includes a number of particular ideas, not one of which constitutes the essence of the general idea: for there are animals which have no intelligence, no will, no progressive motion, no flesh or blood, and appear to be only a mass of congealed mucilage: there are others which cannot seek for their food, and only receive it from the element in which they exist; others have no senses, not even that of feeling, at least in a perceptible degree. Some have no sexes, or have both in one individual. There remains nothing, therefore, in the properties of an animal, but the power of reproduction, which is common to both the vegetable and animal. It is from the whole taken together that a general idea must be formed; and as this whole is composed of different parts, there must of necessity be degrees or intervals between these parts. An insect, in this sense, is less an animal than a dog, an oyster than an insect, and a sea nettle, or a fresh water polypus, than an oyster: and, as Nature proceeds by insensible degrees, we should find beings partaking of still less animation than a sea nettle or a polypus. Our general ideas are only artificial methods of collecting a number of objects under one point of view; and they have, like other artificial methods, the defect of not being

able to comprehend the whole. They are in direct opposition to the procedure of Nature, which is uniform, insensible, and always particular. It is to grasp a number of particular ideas under one word, of which we have no clearer notion than that word conveys; because, when the word is once received, we imagine it to be a line drawn between the different productions of Nature; that every thing above this line is an *animal*, and every thing below it a *vegetable*, which is another word equally general, and employed as a line of separation between organized bodies and brute matter. But, as has already been remarked, these lines of separation have no existence in nature. There are bodies which are neither animals, vegetables, nor minerals: and every attempt to arrange them under either of these classes must be ineffectual. For example, Mr. Trembly, when he first examined the fresh water polypus, spent much time before he could determine whether it was an animal or a vegetable. The reason is plain; this polypus is perhaps neither the one nor the other; and all that can be said is, that it has most resemblance to an animal: and as we are inclined to think, that every organized being is either an animal or a plant, we believe not the existence of any organized body, unless it falls under some of these general denominations, although there must be, and in fact there are, many beings which belong neither to the one nor the other. The moving bodies found in the seminal fluids, and in infusions of the flesh

of animals as well as in those of all parts of vegetables, are of this species: we can neither rank them under animals nor vegetables; and no man in his senses will ever maintain them to be minerals.

We may, therefore, pronounce, without hesitation, that the great division of natural productions into *animals*, *vegetables*, and *minerals*, comprehends not all material beings; since beings exist which can be included in none of these classes. Nature passes by imperceptible steps from the animal to the vegetable; but, from the vegetable to the mineral, the passage is sudden, and the interval great. Here the law of imperceptible degrees suffers a violation. This circumstance made me suspect, that, by examining Nature more closely, we should find intermediate organized beings, which, without having the faculty of reproduction, like animals and vegetables, would still enjoy a species of life and motion; beings which, without having the properties either of animals or vegetables, might enter into the constitution of both; and, lastly, beings which would consist of the first assemblages of the organic particles mentioned in the preceding chapters.

Eggs constitute the first class of this species of beings. Those of hens and other female birds are attached to a common pedicle, and derive their nourishment and growth from the body of the animal. But, when attached to the ovarium, they are not properly eggs; they are only yellow globes, which separate from the ova-

rium as soon as they acquire a certain magnitude: such is their internal organization, however, that they absorb nourishment from the lymph contained in the uterus, and convert it into the white, membranes, and shell. Thus the egg possesses a species of life and organization. It grows and assumes a form by its own peculiar powers: it neither lives like an animal, nor vegetates like a plant, nor enjoys the faculty of reproduction. The egg, therefore, is a distinct being, which can neither be ranked with the animal nor mineral kingdoms. If it be alleged, that the egg is only an animal production destined for the nourishment of the chick, and ought to be regarded as a part of the hen; I reply, that eggs, whether impregnated or not, are always organized in the same manner; that impregnation changes only a part which is almost invisible; that it grows, and acquires a uniform figure and structure, both externally and internally, independent of impregnation; and, consequently, it ought to be considered as a separate and distinct being.

This will be still more apparent, if we attend to the growth and formation of the eggs of fishes. When the female deposits them in the water, they are properly but the rudiments of eggs, which, being lately separated from the body of the animal, attract and assimilate those particles that are fitted for their nourishment; and thus increase in size by mere absorption. In the same manner as the egg of the hen acquires its white and membranes while floating

in the uterus, the eggs of fishes acquire their white and membranes in the water; and, whether they are fecundated by the male's shedding his milt upon them, or they remain unimpregnated, they still arrive at full perfection. It is plain, therefore, that eggs in general ought to be regarded as organized bodies, and as forming a distinct genus from animals and vegetables.

The organized bodies found in the semen of all animals, and which, like those in the milt of the calmar, are natural machines, and not animals, form a second species of the same genus. They are properly the first assemblages of those organic particles so often mentioned; and, perhaps, they are the organic particles of all animated bodies. They appear in the semen of every animal, because the semen is only the residue of the organic particles which the animal takes in with its food. The particles, as formerly remarked, assimilated from the food, are those which are most organized, and most analogous to the animal itself: it is of these particles that the semen consists; and, of course, we ought not to be surprised to find organized bodies in that fluid.

To be satisfied that these organized bodies are not real animals, we have only to reflect upon the preceding experiments. The moving bodies in the semen have been considered as real animals, because they have a progressive motion, and something similar to tails. But, after attending, on the one hand, to the nature of this motion, which is suddenly finished, and never again

commences, and, on the other, to the nature of the tails, which are only threads adhering to the moving body, we will begin to hesitate; for an animal goes sometimes slow, and sometimes fast; and it sometimes stops, and reposes, without moving at all. These moving bodies, on the contrary, go always in the same direction at the same time; I never saw them stop and again begin to move; and, if they once stop, it is for ever. I demand, if this continued motion, without any repose, is common to animals; and if, from this circumstance, we ought not to doubt concerning the real animation of these moving bodies? An animal should always have a uniform figure, as well as distinct members: but these moving bodies change their figure every moment; they have no distinct members; and their tails are only adventitious matter, and no part of the individual. How, then, can they be esteemed real animals? In seminal liquors, we see filaments which stretch out, and seem to vegetate; then they swell, and produce moving bodies. These filaments are, perhaps, of a vegetable nature; but the moving bodies which proceed from them cannot be animals; for we have no example of vegetables giving birth to animals. Moving bodies are found in all animal and vegetable substances promiscuously. They are not the produce of generation. They have no uniformity of species. They cannot, therefore, be either animals or vegetables. As they are to be met with in every part of animals and of vegetables, but are most abundant in their seeds, is it

not natural to regard them as the organic living particles of which animals and vegetables are composed, as particles which, being endowed with motion, and a species of life, ought to produce, by their union, moving and living beings, and, in this manner, form animals and vegetables?

But, to remove every doubt upon this subject, let us attend to the observations of others. Can the active machines discovered by Mr. Needham in the milt of the calmar be regarded as animals? Can we believe that eggs, which are active machines of another species, are also animals? If we examine Leeuwenhoek's representations of the moving bodies found in many different substances, shall we not be satisfied, at the first inspection, that they are not animals, since none of them have any members, but are uniformly either round or oval? If we attend to what this famous observer has remarked, concerning the motion of these pretended animals, we must be convinced that he was wrong in regarding them as real animals, and we shall be more and more confirmed in the opinion, that they are only organic moving particles. We shall give some examples. Leeuwenhoek * gives the figure of the moving bodies in the seminal fluid of a male frog. This figure represents nothing but a thin, long body, pointed at one of the extremities. Let us attend to what he says concerning it: "Uno tempore caput (that is, the largest extre-

* Tom. i. p. 51.

mity of the moving body) crassius mihi apparebat alio; plerumque agnoscebam animalculum haud ulterius quam a capite ad medium corpus, ob caudæ tenuitatem, et cum idem animalculum paulo vehementius moveretur (quod tamen tarde *fiebat) quasi volumine quodam circa caput ferebatur.* Corpus fere carebat motu, cauda tamen in tres quatuorve flexus volvebatur." Here we have the change of figure that I had observed, the mucilage from which the moving bodies with difficulty disengage themselves, the slowness of their motion before they escape from the mucilage, and, lastly, a part of the pretended animal in motion while the other is dead: for, a little afterwards, he observes, "movebant posteriorem solum partem, quæ ultima morti vicinia esse judicabam." All this is repugnant to the nature of an animal, but exactly corresponds with my experiments, except that I never saw the tail move, but in consequence of an agitation of the body. Speaking of the seminal fluid of the cod, he says *, "Non est putandum omnia animalcula in semine aselli contenta uno eodemque tempore vivere, sed illa potius tantum vivere quæ exitui seu partui viciniora sunt, quæ et copiosiori humido innatant præ reliquis vita carentibus, adhuc in crassa materia, quam humor eorum efficit, jacentibus." If these are animals, why were they not all alive? Why did those only live which were in the most fluid part of the liquor? Leeuwenhoek did not observe.

* Page 52.

that the thick part, instead of being a humour produced by the animalcules, is a mucilage, which gives birth to them. If he had diluted the mucilage with water, he would at once have given life and motion to the whole. The mucilage itself is often nothing else than a mass of those bodies, which begin to move as soon as they can disengage themselves; and, of course, this thick matter or mucilage, instead of being a humour produced by the animalcules, is only a congeries of the animals themselves, or rather, as formerly remarked, the matter of which they are formed. Speaking of the semen of the cock, Leeuwenhoek, in his letter to Grew, says *, "Contemplando materiam (seminalem) animadverti ibidem tantam abundantiam viventium animalium, ut ea stuperem; forma seu externa figura sua nostrates anguillas fluviatiles referebant, vehementissima agitatione movebantur; quibus tamen substrati videbantur multi et admodum exiles globuli, item multæ plan-ovales figuræ, quibus etiam vita posset attribui, et quidem propter earumdem commotiones; sed existimabam omnes hasce commotiones et agitationes provenire ab animalculis, sicque etiam res se habebat; attamen ego non opinione solum, sed etiam ad veritatem mihi persuadeo has particulas, planam et ovalem figuram habentes, esse quædam animalcula inter se ordine suo disposita et mixta, vitaque adhuc carentia." Here we have animalcules, in the same seminal fluid,

* Page 5.

of different forms; and I am convinced, from my own experiments, that, if Leeuwenhoek had observed those oval bodies with attention, he would have perceived that they moved with their own proper force, and, consequently, that they were as much alive as the others. This change of figure, it is true, exactly corresponds with what I had observed: but it does not indicate a uniform species of animals; for, in the present example, if the bodies having the figure of a serpent were genuine spermatic animalcules, each of which was destined to become a cock, and therefore implies a uniform and invariable organization, which was the end and destination of those of an oval figure? He, indeed, afterwards remarks, that these oval bodies might be the same with the serpentine, if we suppose them rolled up in a spiral manner. But still, how is it possible to conceive that an animal, with its body in this restrained posture, should be able to move without extending itself? I, therefore, maintain, that these oval bodies were only the organic particles separated from their threads or tails, and that the serpentine bodies were the same particles, which had not yet been deprived of these appendages, as I have often remarked in other seminal fluids.

Besides, Leeuwenhoek, who believed all these moving bodies to be real animals, who established a system upon that foundation, and who affirmed that spermatic animalcules were transformed into men and other animals, now suspected them to be only natural machines, or moving

organic particles. He never entertained a doubt, but that these animalcules contained the large animal in miniature. He remarks*, "Progeneratio animalis ex animalculo in seminibus masculinis omni exceptione major est; nam, etiamsi in animalculo ex semine masculo, unde ortum est, figuram animalis conspicere nequeamus, attamen satis superque certi esse possumus figuram animalis ex qua animal ortum est, in animalculo, quod in semine masculo reperitur, conclusam jacere sive esse: et quanquam mihi sæpius, conspectis animalculis in semine masculo animalis, imaginatus fuerim me posse dicere, en ibi caput, en ibi humeros, en ibi femora; attamen cum minima quidem certitudine de iis judicium ferre potuerim, hucusque certi quid statuere supersedeo, donec tale animal, cujus semina mascula tam magna erunt, ut in iis figuram creaturæ ex qua provenit agnoscere queam, invenire secunda nobis concedat fortuna." This opportunity, so much desired by Leeuwenhoek, happily occurred to Mr. Needham. The spermatic animals of the calmar are three or four lines in length, and are visible without the assistance of the microscope. Their whole parts and organization are easily perceived. But they are by no means small calmars, as Leeuwenhoek imagined. They are not even animated, though they have motion, but are only machines, which ought to be regarded as the first union of the organic particles.

* Page 67.

Though Leeuwenhoek had not this opportunity of undeceiving himself, he had, however, observed other appearances, which ought to have produced this effect. He had remarked, for example, that the spermatic animals of the dog * often changed their figure, especially when the fluid was nearly evaporated; that, when dead, they had an opening in the head, which did not appear when they were alive; and that the head was full and round during the life of the pretended animal, and flat and sunk after its death: these circumstances should have led him to hesitate concerning the real animation of these bodies, and to think that the phænomena corresponded more with a machine which emptied itself, like that of the calmar, than with the properties of an animal.

I have said that the motion of these moving bodies, these organic particles, is not similar to the motion of animals, and that there is no interval in their movements. Leeuwenhoek, in tom. i. p. 168, makes precisely the same remark: "Quotiescunque," says he, "animalcula in semine masculo animalium fuerim contemplatus, attamen illa se unquam ad quietem contulisse, me nunquam vidisse, mihi dicendum est, si modo sat fluidæ superesset materiæ in qua sese commode movere poterant; at eadem in continuo manent motu, et, tempore quo ipsis moriendum appropinquante, motus magis magisque deficit, usquedum nullus prorsus motus in illis

* See tom. i. p. 160.

agnoscendus sit." It is difficult to conceive, that animals should exist, which, from the moment of their birth to their dissolution, should continue to move rapidly, without the smallest interval of repose; or to imagine that the spermatic animals of the dog, which Leeuwenhoek perceived to be as active on the seventh day as the moment they proceeded from the body of the dog, should be able, during all this time, to move with a celerity which no animal on earth could persist in for a single hour, especially when the resistance arising from the density and tenacity of the fluid is taken into consideration. This species of continued motion, on the contrary, has an exact correspondence to the nature of the organic particles, which, like artificial machines, produce their effects by a continued operation, and stop immediately afterwards.

In the numerous experiments made by Leeuwenhoek, he doubtless observed spermatic animals without tails. He even mentions them in some places, and endeavours to explain the phænomenon. For example, speaking of the semen of the cod, he says*, "Ubi vero ad lactium accederem observationem, in iis partibus quas animalcula esse censebam, neque vitam neque caudam dignoscere potui; cujus rei rationem esse existimabam, quod quamdiu animalcula natando loca sua perfecte mutare non possunt, tamdiu etiam cauda concinne circa corpus maneat ordinata, quodque ideo singula animalcula rotundum

* Tom. ii. p. 150.

repræsentent corpusculum." It would have been more simple, and more agreeable to truth, to have said, that the spermatic animals of this fish sometimes have tails, and sometimes have none, than to suppose that the tails were so exactly wound round their bodies as to give them a spherical figure. One would be apt to think, that Leeuwenhoek had never fixed his eyes upon, or described any moving particles but those which had tails; he has given figures of none that wanted tails, because, though they moved, he did not regard them as animals. This is the reason why all Leeuwenhoek's figures of spermatic animals are very similar, and all drawn with tails. When they appeared in any other form, he thought they were imperfect, or, rather, that they were dead. Besides, it is apparent from my experiments, that, instead of unfolding their tails, wherever they are placed in circumstances proper for swimming, as Leeuwenhoek insists, these pretended animals gradually lose their tails, in proportion to the rapidity of their motions, till, at last, these tails, which are bodies foreign to the animalcules, or threads which they drag after them, totally disappear.

Leeuwenhoek, speaking of the spermatic animals of man*, says: "Aliquando etiam animadverti inter animalcula particulas quasdam minores et subrotundas; cum vero se ea aliquoties eo modo oculis meis exhibuerint, ut mihi imaginarer eas exiguis instructas esse caudis,

* Tom. iii. p. 93.

cogitare cœpi annon hæ forte particulæ forent animalcula recens nata; certum enim mihi est ea etiam animalcula per generationem provenire, vel ex mole minuscula ad adultam procedere quantitatem: et quis scit annon ea animalcula, ubi moriuntur, aliorum animalculorum nutritioni atque augmini inserviant!" It appears from this passage, that Leeuwenhoek had seen, in the human semen, animalcules without tails; and that he is obliged to suppose them to be recently produced, which is directly the reverse of what I have observed; for the moving bodies are never larger than when they separate from the filaments, which is the period when their motion begins: but, as soon as they are fully disengaged from the mucilage, they become smaller, and continue to diminish till their motion entirely ceases. With regard to the generation of these animals, which Leeuwenhoek imagines to be certain, no vestige of copulation has been discerned by the most acute observers. It is purely a random assertion, as may be easily proved from his own experiments. He remarks, for example, with great propriety, that the milt of the cod* is gradually filled with seminal liquor; and that, after the fish has spent this liquor, the milt dries, and leaves only a flaccid membrane, entirely destitute of every kind of fluid. "Eo tempore," says he, "quo asellos major lactes suos emisit, rugæ illæ, seu tortiles lactium partes, usque adeo contrahuntur, ut nihil præter pelliculas seu mem-

* Tom. iii. p. 98.

branas esse videantur." *How should this dry* membrane, which contains neither seminal liquor nor animalcules, produce animalcules *of the same* species next season? If they were produced by a regular generation, such a long interruption could not take place, which, in most fishes, continues a whole year. To remove this difficulty, he afterwards remarks: "Necessario statuendum erit, ut asellus major semen suum emiserit, in lactibus etiamnum multum materiæ seminalis gignendis animalculis aptæ remansisse, ex qua materia plura oportet provenire animalcula seminalia quam anno proxime elapso emissa fuerant." This supposition, that part of the seminal liquor remains in the milt for the production of spermatic animals the following year, is perfectly gratuitous, and contrary to observation; for the milt, during this interval, is nothing but a thin dry membrane. But how will he explain a phænomenon that takes place in some fishes, and particularly in the calmar, whose seminal liquors are not only renewed every year, but even the membranes which contain them: here neither the milt nor the seminal liquor are preserved till the succeeding year; and, of course, their regular reproduction cannot be ascribed to generation. It is, therefore, apparent, that these pretended spermatic animals are not multiplied, like other animals, by generation; and this circumstance alone would entitle us to conclude that the moving particles in the seminal fluid are not real animals. Leeuwenhoek, though he tells us, in

the passage above quoted, that the spermatic animals are certainly propagated by generation, acknowledges, however, in another place*, that the manner in which these spermatic animals are produced, is exceedingly obscure, and that he leaves to others the farther elucidation of this subject. "Persuadebam mihi," says he, speaking of the spermatic animals of the dormouse, "hæcce animalcula ovibus prognasci, quia diversa in orbem jacentia et in semet convoluta videbam; sed unde, quæso, primam illorum originem derivabimus! an animo nostro concipiemus horum animalculorum semen jam procreatum esse in ipsa generatione, hocque semen tam diu in testiculis hominum hærere, usquedum ad annum ætatis decimum-quartum vel decimum-quintum aut sextum pervenerint, eademque animalcula tum demum vita donari, vel in justam staturam excrevisse, illoque temporis articulo generandi maturitatem adesse! sed hæc lampada aliis trado." It is, perhaps, unnecessary to make many remarks on what Leeuwenhoek has here advanced. He saw, in the semen of the dormouse, spermatic animals which were round and without tails; "in semet convoluta," says he, because he always supposes that they ought to have tails. He was formerly certain that these animals were propagated by generation: here he seems to be convinced of the reverse. But, when he learned, that the vine-

* Tom. i. p. 26.

fretters (*pucerons*) were propagated without copulation*, he laid hold of this idea, in order to explain the generation of spermatic animals. "Quemadmodum," says he, "animalcula, hæc quæ pediculorum antea nomine designavimus (the pucerons) dum adhuc in utero materno latent, jam prædita sunt materia seminali ex qua ejusdem generis proditura sunt animalcula, pari ratione cogitare licet animalcula in seminibus masculinis ex animalium testiculis non migrare, seu ejici, quin post se relinquant minuta animalcula, aut saltem materiam seminalem ex qua iterum alia ejusdem generis animalcula proventura sunt, idque absque coitu, eadem ratione qua supradicta animalcula generari observavimus." This supposition is not more satisfactory than the preceding; for, by thus comparing the generation of spermatic animalcules with that of the vine-fretter, we discover not the reason why they are never seen in the human semen till the age of fourteen or fifteen; nor do we learn whence they proceed, or how they are yearly renewed in fishes, &c. Notwithstanding all the efforts of Leeuwenhoek to establish the generation of spermatic animals, he leaves the subject in the greatest obscurity, where it probably would have for ever remained, if we had not discovered, by the preceding experiments, that they are not animals, but organic moving particles, contained originally in the food, and found in vast numbers in the

* See tom. ii. p. 499, et tom. iii. p. 271.

seminal liquors of animals, which are the most pure and most organic extracts derived from the food.

Leeuwenhoek acknowledges, that he did not always find animalcules in the male semen; for example, in that of the cock, which he often examined, he never but once saw the eel-like animalcules: and, some years after, he could not discover these eels *, but found animalcules with a large head and a tail, which his draughtsman could not perceive. He likewise remarks, that, during one season, he could not discover living animals in the seminal fluid of the cod †. All these disappointments proceeded from this circumstance, that, though he saw moving globules, he was unwilling to acknowledge them to be animals, unless they had tails, though it is in the form of globules that they most generally appear, either in seminal fluids, or in infusions of animal and vegetable substances. In the same place, he remarks, that, though he had often distinctly seen the spermatic animals of the cod, he was never able to make his draughtsman perceive them: "Non solum," says he, "ob eximiam eorum exhilitatem, sed etiam quod eorum corpora adeo essent fragillia, ut corpuscula passim dirumperenter; unde factum fuit ut nonnisi raro, nec sine attentissima observatione, animadverterem particulas planas atque ovorum in morem longas, in quibus ex parte caudas dignoscere licebat; particulas has oviformes ex-

* See tom. iii. p. 370. † Ibid. p. 306.

istimavi animalcula esse dirupta, quod particulæ hæ diruptæ quadruplo fere viderentur majores corporibus animalculorum vivorum." When an animal, whatever be its species, dies, it does not suddenly change its form; from being long like a thread, it does not become round like a bullet; neither does it become four times as large after as before death. Not a single article of what is advanced by Leeuwenhoek, in this passage, has the smallest correspondence to the nature of an animal; but, on the contrary, the whole agrees with a species of machines, which, like those of the calmar, burst and empty themselves, after having performed their functions. To pursue this observation a little farther: he tells us, that he has seen the spermatic animals of the cod under different forms, "Multa apparebant animalcula sphæram pellucidam repræsentantia," and of different sizes, "Hæc animalcula minori videbantur mole, quam ubi eadem antehac in tubó vitreo rotundo examinaveram." This is an evident proof that there is nothing like a uniform and invariable species in these animalcules, and, consequently, that they are not animals, but only organic moving particles, which, by their different combinations, assume various figures and sizes. Of these organic particles, vast numbers appear in the extract and in the residue of our food. The matter which adheres to the teeth, and which, in healthy persons, has the same smell with the seminal fluid, is only a residue of our food. In it we accordingly find a great quantity of these

pretended animals, some of which have tails, and resemble those of the seminal fluid. Mr. Baker has given figures of four species of them, which are all a kind of cylinders, ovals, or globules, some of them having tails, and others not. But, after the strictest examination, I am persuaded, that none of them are real animals, and that they are only, like those in the semen, the organic living particles of the food appearing under different forms. Leeuwenhoek, who knew not how to account for these pretended animals in the matter adhering to the teeth, supposes them to proceed from certain species of food, as cheese, in which they previously existed; but they are found among the teeth of every person, whatever kind of food be eaten; and, besides, they have no resemblance to mites, or other animalcules which appear in corrupted cheese. In another place, he tells us that these teeth animals proceed from the cistern water which we drink, because he observed similar animals in rain water, especially when it had stagnated upon leaden roofs. But, when we give the history of microscopic animals, we shall demonstrate, that most of those found in rain water are only organic moving particles, which divide, unite, change their size and figure, and, in a word, which can be made to move or to rest, to live or die, as often as we please.

Most seminal fluids spontaneously dilute, or become more liquid, when exposed to the air or to a certain degree of cold, than when they issue from the body. But they thicken upon the ap-

plication of a moderate degree of heat. I exposed some of these fluids to a degree of cold equal to that of water just beginning to freeze; but the pretended animalcules suffered not the least injury from it. They moved with equal activity, and during the same length of time, as those to which no cold had been applied. But those which were exposed to a small degree of heat, soon ceased to move, because the liquor thickened. If these moving bodies were animals, they differed in their nature and constitution from all others, to which a moderate degree of heat communicates force and motion, and upon whose bodies cold has the very opposite effects.

Before leaving this subject, upon which I have, perhaps, dwelt too long, I must still add another remark, which may lead to some useful conclusions. These pretended spermatic animals, which are nothing but the organic living particles of food, exist, not only in the seminal fluids of both sexes, and in the remnants of food that adhere to the teeth, but likewise in the chyle and in the excrements. Leeuwenhoek, having met with them in the excrements of frogs, and of other animals which he dissected, was at first greatly surprised; and, not being able to conjecture from whence animals could proceed so similar to those in the seminal liquor he had just been examining, he accuses his own want of dexterity, and supposes, that, in dissecting the animal, he had inadvertently opened the seminal vessels, and that the

semen had in this manner been mixed with the fæces. But having afterwards observed the same phænomenon in the fæces of other animals, and even in his own, he was then totally nonplussed. It is worthy of remark, that Leeuwenhoek never found animalcules in his own fæces, but when they were liquid. Whenever his stomach was out of order, and his belly was loose, the animalcules appeared; but, when his food was properly concocted, and his fæces were hard, not a single animalcule was to be found, although he diluted the fæces with water. These facts seem perfectly to coincide with what we formerly advanced; for, when the stomach and intestines properly perform their functions, the fæces are only the gross dregs of the aliment, and all the nourishing and organic particles are absorbed by the lecteal vessels: in this case we cannot expect to find organic particles in the fæces, which are solely composed of the useless and inert part of our food. But, when the stomach and intestines, from any indisposition, allow the food to pass without being properly digested, then the organic particles mix with the fæces; and when examined with the microscope, we discover them in the form of living organic bodies. Hence we may conclude, that people who are troubled with looseness should have less seminal liquor, and be less fitted for the purposes of generation, than those of a contrary habit of body.

I have all along supposed that the female furnishes a fluid equally necessary to generation as

that of the male. In the first chapter, I endeavoured to prove that every organized body contains living organic particles; and, in chap. ii. and iii. that nutrition and reproduction are effects of the same cause; that nutrition is performed by absorption, or an intimate penetration of organic particles through all parts of the body; and that reproduction is effected by the surplus of these same organic particles, collected from every part of the body, and deposited in the reservoirs destined for that purpose. In chap. iv. I have shown how this theory applies to the generation of man, and other animals which have different sexes. Females being organized bodies, as well as males, they must also have some reservoirs for the reception of the surplus of organic particles returned from all parts of their bodies. This surplus, as it is extracted from every part of the body, must appear in the form of a fluid; and it is this fluid to which I have given the appellation of the female semen.

This fluid is not inert, as Aristotle pretends, but prolific, and equally essential to generation as the semen of the male. It contains particles distinctive of the female sex, as that of the other sex contains particles proper for the constitution of male organs; and both of them contain all the other organic particles which may be regarded as common to the two sexes: and hence, from a mixture of the two, the son may resemble his mother, and the daughter her father. Hip-

pocrates maintains, that the semen consists of two fluids, one strong, which produces males, and the other weak, which produces females. But, as the seminal fluid is extracted from every part of the body, it is impossible to conceive how the body of a female should produce particles proper for the formation of male organs.

This liquor must enter, by some way or other, into the uterus of viviparous animals; and, in oviparous animals, it must be absorbed by the eggs, which may be regarded as portable matrixes. Each of these matrixes, or eggs, contains a small drop of the female fluid, in that part which is called the cicatrice. This prolific drop, when the female has had no communication with the male, assumes, as Malpighius observes, the form of a mole, or inorganic mass; but, when it is penetrated by the semen of the male, it produces a fœtus, which is nourished and brought to perfection by the juices of the egg.

Eggs, therefore, instead of being common to all females, are only instruments employed by Nature for supplying the place of uteri in those animals which are deprived of this organ. Instead of being active and essential to the first impregnation, eggs are only passive or accidental parts, destined for the nourishment of the fœtus, already formed in a particular part of this matrix, by the mixture of the male and female semen. Instead of existing from the creation, and each including within itself an infinity of

males and females, eggs, on the contrary, are bodies composed of a superfluous part of the food, which is more gross, and less organic, than that of which the seminal fluid consists. The egg, in oviparous females, answers the same purposes as the uterus and menstrual flux in the viviparous.

To evince that eggs are destined by Nature only to supply the place of an uterus in such animals as are deprived of this organ, we must consider, that females produce eggs independent of the male. The uterus, in viviparous animals, is a part peculiar to the female sex; in the same manner, female fowls, that want this organ, have the defect amply supplied by the successive producion of eggs, which must necessarily exist in these females, independent of all communication with the male. To pretend that the fœtus preexisted in the egg, and that eggs are contained, *ad infinitum*, within each other, is equally ridiculous as to maintain that the fœtus preexisted in the uterus, and that the uterus of the first female contained all the uteri that ever were or will be produced.

Anatomists have applied the term *egg* to things of very opposite natures. Harvey, in his aphorism, *Omnia ex ovó*, by the word *egg*, when applied to oviparous animals, means only the bag which includes the fœtus and all its appendages. He imagined that he perceived the formation of this egg or bag immediately after the junction of the male and female. But this egg proceeded

not from the ovarium of the female: he even asserts that he could not distinguish the smallest alteration in the ovarium. It is apparent, that there is not here the most distant analogy to what is commonly understood by the word *egg*, unless, perhaps, the figure of the bag might have some faint resemblance to that of an egg. Harvey, though he dissected many viviparous females, never could perceive any change in their ovaria: he even regards them as glands totally unconnected with the purposes of generation *, though, as we have seen, they undergo very considerable changes. This able anatomist was deceived by the smallness of the glandulous bodies in animals of the deer kind, to which his researches were principally confined. Conradus Peyerus, who made many observations on the testicles of female deer, remarks, "Exigui quidem sunt damarum testiculi, sed post coitum fœcundum, in alterutro eorum, papilla, sive tuberculum fibrosum, semper succrescit; scrofis autem prægnantibus tanta accidit testiculorum mutatio, ut mediocrem quoque attentionem fugere nequeant †." This author ascribes, with propriety, the reason why Harvey observed no changes in the testicles of the deer, to their smallness. But he is wrong when he tells us, that the changes he had remarked, and which had escaped Harvey, never happened but after impregnation.

* See Harvey, Exercit. 64 and 65.

† See Conrad. Peyer. Merycolog.

Harvey was deceived in several other essential articles. He insists, that the semen never enters the uterus, and that it is impossible it should find admittance; and yet Verheyen found a great quantity of male semen in the uterus of a cow, which he dissected six hours after copulation*. The celebrated Ruysch informs us, that, in dissecting a woman who had been killed immediately after the act of adultery, he found a considerable quantity of male semen, not only in the uterus, but in the Fallopian tubes†. Valisnieri likewise assures us, that Fallopius, and other anatomists, had discovered male semen in the uteri of several women. This point, therefore, though denied by Harvey, is established by the positive testimony of several able anatomists, and particularly by Leeuwenhoek, who found male semen in the uteri of many different species of females.

Harvey mentions an abortion, in the second month, as large as a pigeon's egg, without any appearance of a fœtus. In this also he must have been deceived; for Ruysch, and several other anatomists, maintain, that the fœtus is distinguishable by the naked eye, even in the first month of pregnancy. In the History of the French Academy, we have an account of a fœtus completely formed on the twenty-first day after impregnation. If, to these authorities, we

* See Verheyen, Sup. Anat. tra. 5, cap. 3.

† See Ruysch Thes. Anat. p. 90, tab. vi. fig.

add that of Malpighius, who distinguished the chick in the cicatrice immediately after the egg issued from the body of the hen, we cannot hesitate in pronouncing that the fœtus is formed immediately after copulation; and, consequently, no credit is due to what Harvey says concerning the increase of the parts by juxta-position; since these parts exist from the beginning, and gradually expand till the fœtus be perfectly mature.

De Graaff differs widely from Harvey in his acceptation of the word *egg*. He maintains, that the female testicles are real ovaria, and contain eggs similar to those of oviparous animals, except that they are much smaller, never fall out of the body, nor detach themselves till after impregnation, when they descend from the ovarium into the uterus. The experiments of De Graaff have contributed more to the belief of the existence of eggs than those of any other anatomist. They are, notwithstanding, totally void of foundation; for this celebrated author, in the first place, mistakes the vesicles of the ovarium for eggs, though they are inseparable from the ovarium, form a part of its substance, and are filled with a species of lymph. 2. He is still more deceived, when he informs us, that the glandulous bodies are only the coverings of these eggs or vesicles; for it is certain, from the observations of Malpighius and of Valisnieri, and from my own experiments, that the glandulous bodies contain no vesicles. 3. He is wrong in maintaining that the

glandulous bodies never appear till after impregnation. On the contrary, these bodies are uniformly found in all females, after the age of puberty. 4. He errs in supposing that the globules which he saw in the uterus, and which contained the fœtuses, were the very vesicles that had descended from the ovarium into the uterus, and that, he remarks, had become ten times smaller than when they were in the ovarium. This circumstance alone of their diminished size should have convinced him of his mistake. 5. He is equally unfortunate in maintaining that the glandulous bodies are only the coverings of the fecundated eggs, and that the number of coverings or empty follicles always correspond to the number of fœtuses. This assertion is the reverse of truth; for, on the testicles of all females, we uniformly find a greater number of glandulous bodies, or cicatrices, than of fœtuses actually produced; and they even appear in those which never brought forth. To this we may add, that neither he, Verheyen, nor any other person, ever saw the egg in this pretended covering, or in its follicle, though they have thought proper to rest their system upon that supposition.

Malpighius, who distinguished the growth of the glandulous bodies in the female testicle, was deceived when he imagined that he once or twice discovered the egg in their cavities; for this cavity contains only a fluid; besides, after numberless experiments, no man has ever been able

to discover any thing that had the most distant resemblance to an egg.

Valisnieri, who is never deceived with regard to facts, is wrong in maintaining that the egg must exist in the glandulous body, though neither he, nor any man else, was ever able to discover it.

Let us now attend to what may be esteemed the real discoveries of these anatomists. De Graaff was the first who discovered that the testicles of females suffered any change; and he was right in maintaining that they were parts essentially necessary to generation. Malpighius demonstrated, that the glandulous bodies gradually grew to maturity, and that, immediately after, they were obliterated, and left behind them a slight cicatrice only. Valisnieri illustrated this subject still farther. He discovered that these glandulous bodies were found in the testicles of all females; that they were considerably augmented in the season of love; that they increased at the expense of the lymphatic vesicles of the testicle; and that, during the time of their maturity, they were hollow and full of liquor. These are all the truths we have learned concerning the pretended ovaria and eggs of viviparous animals: what conclusions are we to draw from them? Two things appear to be evident: the one, that no eggs exist in the testicles of females; the other, that there is a fluid both in the vesicles of the testicle, and in the cavity of the glandulous bodies; and we have demonstrated, in the pre-

ceding experiments, that this last fluid is the true female semen, because it contains, like that of the male, spermatic animals, or rather organic particles, in motion.

The seminal fluid of females, therefore, being thus fully ascertained, after what has been said, we must be satisfied that the seminal fluid in general is the superfluous organic part of our food, which is transmitted from all parts of the body to the testicles and seminal vessels of males, and to the testicles and glandulous bodies of females. This liquor, which issues through the nipples of the glandulous bodies, perpetually bedews the Fallopian tubes, and may easily find admission into them, either by absorption, or by the small aperture at their extremity, and in this manner may descend into the uterus. But, on the supposition of the existence of eggs, which are ten or twenty times larger than the aperture of the tubes, it is impossible to conceive the possibility of their being transmitted to the uterus.

The liquor shed by females in the paroxysm of love, which De Graaff supposes to proceed from lacunæ about the neck of the uterus and the orifice of the urethra, may be a portion of the superfluous fluid that continually distills from the glandulous bodies upon the Fallopian tubes. But perhaps this liquor may be a secretion of a different kind, and no way connected with generation. To decide this question, microscopic observations would be necessary; but *all* experiments are not permitted even to philosophers.

I am inclined to think, that, in this liquor, the same spermatic animals, or moving bodies, would be found, as appear in the fluid of the glandulous bodies. Upon this subject, I might quote the authority of an Italian physician, who had an opportunity of trying this experiment, which is thus related by Valisnieri*: "Aggiugne il lodato sig. Bono d'avergli anco veduti (animali spermatici) in questa linfa o siero, diro cosi voluttuoso, che ne tempo dell' amorosa zuffa scappa dalle femine libidinose, senza che si potesse sospettare che fossero di que' del maschio," &c. If the fact be genuine, as I have no reason to doubt, it is certain that this liquor is the same with that contained in the glandulous bodies, and, of course, that it is a real seminal fluid, which escapes through the lacunæ of De Graaff, situated about the neck of the uterus.

Hence we may conclude, that the most libidinous females will be the least fruitful, because they throw out of the body that fluid which ought to remain in the uterus for the formation of the fœtus. We likewise learn why common prostitutes seldom conceive, and why women in warm climates, who have more ardent desires than those of colder regions, are less fertile. But of this we shall afterwards have occasion to treat.

It is natural to imagine that the seminal fluid

* Tom. ii. p. 136.

of either sex should not be fertile, unless when it contains moving bodies. But this point is still undetermined. The Italian physician, mentioned above, alleges, that he never found spermatic animals in his semen till he arrived at forty years, although he was the father of many children, and continued, after the animalcules appeared, to beget more.

The spermatic moving bodies may be regarded as the first assemblages of the organic particles which proceed from all parts of the body; and, when a great number of them unite, they become perceptible by means of the microscope. But, when the number united is small, the body they form is too minute to be visible, and no motion will appear in the seminal fluid, a case which not unfrequently happens. But a long train of successive experiments would be necessary to ascertain the causes of the different states in which this fluid appears.

Of one thing I am certain, from repeated trials, that a seminal liquor, though no motion can be perceived when it is first taken from the body, after being three or four days infused in water, produces as great a number of organic moving particles, as another semen, treated in the same manner, which at first contained vast multitudes. These moving bodies appear likewise in infusions of the blood, of the chyle, of the flesh, and even of the urine, as well as in infusions of all parts of vegetables; and those which appear in all these different substances

seem to have nothing peculiar to them. They all move and act nearly in the same manner. If we will have these bodies to be animated, it must be allowed, that they are very imperfect, and ought to be regarded only as the rudiments of animals, or rather as bodies composed of particles essential to the existence of animals. As Nature's productions are uniform, and advance by imperceptible degrees, there is no improbability in supposing the existence of organized bodies, which properly belong not either to the animal or vegetable kingdoms.

However this matter may stand, it is fully ascertained, that all animal and vegetable substances contain an infinite number of living organic particles. These particles successively assume different forms, and different degrees of activity, according to different circumstances. They are more abundant in the seminal fluids of both sexes, and in the seeds of plants, than in any other part of the animal or vegetable. There exists therefore, in vegetables and animals, a living substance which is common to them both; and this substance is the matter necessary to their nutrition. The animal is nourished by vegetable or animal substances; and the vegetable is nourished by the same substances in a decomposed state. This common nutritive substance is always alive and active. It produces an animal or vegetable, whenever it finds an internal mould or matrix accommodated to the one or the other, as has already been explained. But,

when this active substance is collected too abundantly in a place where it has an opportunity of uniting, it forms, in the animal body, other living creatures, as the tape worm, the ascarides, the worms sometimes found in the veins, in the sinuses of the brain, in the liver, &c. Animals of this kind owe not their existence to the generation of individuals of the same species. It is, therefore, natural to think, that they are produced by an extravasation of the organic matter, or by an inability in the lacteal vessels to absorb the quantity of it presented to them. But we shall afterwards have occasion to examine more in detail the nature of these worms, and of other animals which are produced in a similar manner.

When this organic matter, which may be considered as an universal semen, is assembled in great quantities, as in the seminal fluids, and in the mucilaginous part of the infusions of plants, its first effect is to vegetate, or rather to produce vegetating beings. These zoophytes swell, extend, ramify, and then produce globular, oval, and other small bodies of different figures, all of which enjoy a species of animal life; they have a progressive motion, which is sometimes very rapid and sometimes more slow. The globules themselves decompose, change their figure, and become smaller; and, in proportion as they diminish in size, the rapidity of their motion increases.

I have sometimes imagined that the venom of

the viper, and even the poison of enraged animals, might proceed from this active matter being too much exalted. But I have not yet had leisure for experiments of this kind, nor for ascertaining the nature of different drugs. All I can say at present is, that infusions of the most active drugs abound with moving bodies, and that they appear sooner in them than in other substances.

Almost all microscopic animals are of the same nature with the moving bodies in the seminal fluids, and in infusions of animal and vegetable substances. The eels in paste, in vinegar, &c., are all of the same nature, and derived from the same origin. But the proofs and illustrations relative to this subject, we shall reserve till we give the particular history of microscopic animals.

END OF VOL. II.

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